



2010 DOE Solid-State Lighting
MARKET INTRODUCTION WORKSHOP
July 20–22, 2010 • Philadelphia, Pennsylvania

SSL MARKET INTRODUCTION WORKSHOP REPORT

Solid-State Lighting Portfolio
Building Technologies Program
Office of Energy Efficiency and Renewable Energy
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1. Introduction

More than 300 lighting leaders from across the continent gathered in Philadelphia July 21–22, 2010, for the fifth annual Solid-State Lighting (SSL) Market Introduction Workshop, hosted by DOE. The diverse audience included representatives from industry, government, efficiency organizations, utilities, municipalities, designers and specifiers, retailers, and distributors. The purpose of the workshop was to share the latest insights, updates, and strategies for the successful market introduction of high-quality SSL products.



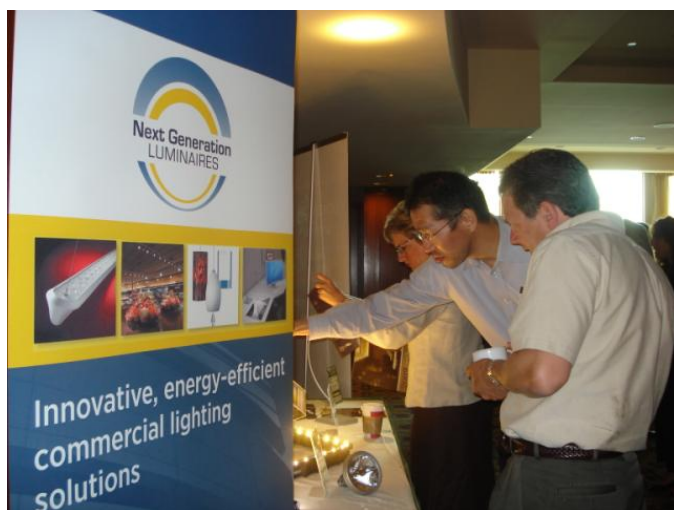
Opening remarks at the 2010 SSL Market Introduction Workshop, Hyatt Regency Penn's Landing in Philadelphia, Pennsylvania

2. Pre-Conference Events

2.1 Tutorials

The two-day workshop was preceded by an optional half-day of free, beginner-level tutorials on July 20. Attended by more than 175 people, these tutorials covered the basics on LED lighting and were intended not only for those new to SSL, but also for those interested in increasing or refreshing their understanding of the field. The tutorial presentations, as well as all SSL Market Introduction Workshop presentations and materials, are posted at www.ssl.energy.gov/philadelphia2010_materials.html.

Michael Poplawski of Pacific Northwest National Laboratory (PNNL) reviewed 18 LED technology fundamentals for novices. Poplawski noted that an LED is a narrow-band light



More than 175 participated in the pre-conference tutorial sessions explaining the basics of solid-state lighting science, research, and technology.

source and reviewed the ways in which it can be made to emit white light. He highlighted the energy-saving potential of LED lighting and discussed major issues such as efficiency, thermal management, lifetime, and cost.

Bruce Kinzey of PNNL reviewed recent experiences with LED lighting, based on the technology's performance in DOE's GATEWAY Demonstration Program. He examined some of the maintenance issues encountered, such as dirt depreciation, and noted that cost is still a factor. Kinzey observed that while there has been rapid advancement of LED technology in terms of cost, performance, and capability, the market is still rife with misinformation and misunderstanding. He concluded that due diligence and preparation are keys to successful implementation of LED lighting products.

Eric Richman of PNNL gave an update on DOE's CALiPER testing program. He focused on the results of the latest CALiPER testing (Round 10), and especially on three new product categories. Richman said LED parking-structure lighting on the whole shows higher efficacy than do traditional benchmarks, and also has better light distribution. He observed that the efficacy of LED wall packs is generally good and that the higher color temperatures are not necessarily a problem, depending on the application. Richman noted that though LED cove lighting falls short of linear fluorescent products in terms of light output and efficacy, it generally equals or outperforms xenon products.

Richman provided an overview of two key SSL standards from the Illuminating Engineering Society of North America (IES). He explained that LM-79, Approved Method for the Electrical and Photometric Measurement of Solid-State Lighting Products, describes how to perform reproducible measurements of LED luminaires based on absolute rather than relative photometry. Richman then described LM-80, Approved Method for Measuring Lumen Maintenance of LED Light Sources, noting that LM-80 does not define or provide methods for estimating lifetime methods, but only for measuring lumen depreciation.

Marci Sanders of D&R International discussed DOE's Lighting Facts[®] label and program, which was created because many LED lighting products do not live up to their claims regarding light output and lifetime. Sanders reviewed the Lighting Facts website as well as the rapidly growing list of registered products, nearly half of which are replacement lamps. She also discussed the key role played by Lighting Facts Partners, which include retailers, distributors, and lighting professionals, and noted that their ranks are also growing rapidly.

Kelly Gordon of PNNL discussed how to compare the performances of LED integral replacement lamp products. She reviewed the different types of LED integral replacement lamps, including omnidirectional, decorative, MR16, PAR/R, and linear. Illustrating her points with recent CALiPER testing results, Gordon talked about how and what to compare among replacement lamps, focusing on their light output, intensity distribution, and color quality.

Jason Tuenge of PNNL reviewed key questions to ask when evaluating LED products. In addition to determining the quantity, quality, and location of light needed, he stressed the importance of finding out how long the light source is expected to last, how it can be replaced, and whether it is compatible with other hardware. It is also helpful to determine how much

energy will be saved and whether performance claims are backed by trustworthy test data as well as by a warranty. Tuenge identified the product's safe operation as another key concern and suggested considering hiring a qualified lighting professional to minimize risk and increase return on investment, especially with critical applications and large purchases.

2.2 Webcast

Pre-conference events also included a 90-minute webcast (July 20) on evaluating LED street lighting solutions, which could be attended either in person in Philadelphia or online. The webcast, which drew more than 500 attendees in total, focused on the ways in which DOE's Municipal Solid-State Street Lighting Consortium is helping cities across the country make informed decisions and featured three Consortium members who shared their experiences implementing street lighting evaluations.

Tod Rosinbum of the City of Portland, Oregon, cited his city's high electric bill, the aging of its street-lighting infrastructure, and a desire to reduce greenhouse gas emissions and save energy as among the chief reasons for considering LEDs. Another important factor, he said, was the ability to remotely monitor and control LEDs. Rosinbum discussed two Portland GATEWAY demonstration projects that involved LED street lighting. He noted that among the different light sources tested, LEDs provided the best uniformity and the most potential for controls, and that their apparent brightness raised the comfort level of drivers as well as pedestrians.



A comparison of visual uniformity from three types of street lighting tested by the City of Portland, Oregon

Amy Olay of the City of San Jose, California, explained that San Jose is interested in LED street lighting not only to reduce operating and maintenance costs and improve the quality of lighting, but also to take advantage of SSL's directionality, reduce the city's energy consumption and environmental footprint, and reduce sky glow. She discussed a current demonstration project that uses dimming and controls with LED street lighting and identified LED street lighting's main challenges. According to Olay, these include high prices, long returns on investment, variations in product quality among manufacturers, insufficient warranties, and disparity in longevity between the driver and LED chip.

John Walter of National Grid presented a utility's perspective on LED street lighting, focusing on tariffs and rates, product variability, and energy rate development. He cited energy efficiency, environmental friendliness, and long life as key benefits of SSL. His main concerns included component quality, lack of standardization, and manufacturer integrity. Walter reviewed various societal issues that come into play when evaluating street lighting, including sky glow and light

trespass reduction, vehicle and pedestrian safety, and property security. He noted how difficult it is for utilities to create rates for technologies that are too new to have longevity track records.

Edward Smalley of the City of Seattle, who served as webcast moderator, talked about the activities of the Consortium, which he chairs. He noted the influx of Consortium applications from all over the country, observing that applicants run the gamut from huge metropolises to small towns. Smalley discussed the Consortium's recently launched web page for manufacturers to enable them to register their U.S.-made products. He also described a West Coast working group's efforts on remote monitoring and adaptive lighting controls. The Consortium is seeking demonstration sites, and its first annual meeting will be held in September in Huntington Beach, California.

3. Big Changes Ahead

3.1 Welcome

On July 21, DOE SSL Portfolio Manager James Brodrick kicked off Day 1 of the workshop by pointing out that new lighting standards mandated by the Energy Independence and Security Act of 2007 (EISA) will start rolling out in 2012, effectively phasing out lower-efficiency light bulbs and putting an end to the "Incandescent Age." Remarking that the SSL revolution "promises unprecedented levels of energy efficiency," he noted that there are still many unknowns about the technology, as well as much hype and misinformation. Brodrick likened DOE's SSL programs to "the guardrails" that keep swift-moving vehicles from straying off track, and cited the need for education during the formidable learning curve ahead.



Panelists (from left) Jim Brodrick, DOE (moderator); Jason West, D&R International; Hampton Newsome, FTC; Shana Cockerham, D&R International; and Bill Hamilton, The Home Depot

3.2 A Decade of Change

The panel discussion titled "Get Ready: A Decade of Change" looked at the current LED replacement lamp market, where it is headed, and what preparations are needed. Jason West of D&R International presented a market snapshot based on data from DOE's Lighting Facts program. In reviewing the upcoming EISA lighting standards, he noted that while current LED omnidirectional replacements meet the required efficacy levels, most can only match the light output of 40W incandescent. West also noted that there are no LED reflector lamp replacements for the highest lumen levels, such as 90W PAR 38, and that LED replacements for linear fluorescent lamps fall below the light output levels of the products they are intended to replace. He emphasized the need for consumer education, cautioning that "consumers are going to have to understand how to make sense of these new products."

Hampton Newsome of the U.S. Federal Trade Commission (FTC) discussed his agency’s new consumer labeling requirements for lamps, which go into effect in 2011. The requirements are based on a multi-format label patterned after DOE’s Lighting Facts label, with lumens and energy cost on the front of the packaging and the “Lighting Facts” on the back. “The changes are intended to help consumers understand the high-efficiency bulbs that are coming out,” he explained, adding that the goal is for people to focus on lumens rather than watts. Newsome also reviewed the FTC’s regulations regarding unfair or deceptive advertising claims, noting that the two overriding principles are to tell the truth and be able to substantiate all claims.

With an eye toward identifying lessons learned, Shana Cockerham of D&R International reviewed the recent experiences of Australia and Europe in implementing lighting standards similar to the impending ones mandated by EISA. She observed that the transitions to more energy-efficient lighting varied considerably, affected by the political environment, the extent of government involvement, and the media’s interpretation of the new lighting standards. Cockerham noted that at least some stockpiling of “old” bulbs occurred in all jurisdictions. Consumer education involving the government working closely with retailers, manufacturers, and utilities would have eased the transitions in many of the countries.

Bill Hamilton of The Home Depot spoke about the need in the coming years for a whole new way to educate consumers that takes into account SSL and other kinds of energy-efficient lighting. Insufficient consumer education, Hamilton asserted, was a major reason behind the failure of the attempt in the 1970s to convert the United States to the metric system. For SSL, he suggested a 360-degree approach that incorporates as many communication networks as possible, e.g., in-store merchandising, public service announcements, utility rebates, and online education. Hamilton advocated giving the transition a positive spin and emphasizing the substantial energy-saving benefits. He noted that the task is daunting, with more than 100 years of a “watts = brightness” mindset to overcome.



According to Hamilton, a comprehensive approach is needed to educate consumers about the upcoming changes in the replacement lamp market.

Brodrick, who acted as moderator, concluded Panel 1 by announcing DOE's plans to launch a major consumer education initiative on the upcoming legislative changes that will impact the lighting market. The goals are to familiarize consumers with lighting options and applications in order to prepare them for the impact of EISA, avoid negative perception of the new lighting requirements, and minimize stockpiling of phased-out bulbs. Joining Brodrick for the announcement were Hamilton of The Home Depot as well as representatives from Costco Wholesale, Grainger, GE, Philips, Cree, and OSRAM SYLVANIA, all of which are on board to work with DOE in this effort. Brodrick said the initiative is still in the planning stage and more details will be available in the coming months.

Question-and-Answer Session

Brodrick was asked whether EISA funding for consumer education has been appropriated. He replied that it has not and emphasized that the DOE education campaign announced at the workshop is not in response to Section 321 of EISA. Another question asked was how to best educate consumers on using LED lighting products? Hamilton said The Home Depot is currently working on that in regard to its point-of-sale signs. In response to a question about plans to address issues such as light distribution, West noted that DOE's Lighting Facts program is starting to look at light distribution. "Our challenge is figuring out how to make this complicated scientific information understandable to the consumer," added Cockerham.

4. Implementing LED Lighting Programs

Ed Schmidt of Northeast Energy Efficiency Partnerships (NEEP) moderated the second workshop panel on strategies and best practices for successfully implementing LED lighting programs. Before introducing the panelists, Schmidt invited the audience to join DOE's Technical Information Network for Solid-State Lighting (TINSSL), which increases awareness of SSL technology, performance, and appropriate applications. TINSSL provides members with regular updates on technical progress, targeted outreach materials, and upcoming meetings and events that address related market issues.



Panelists (from left) Ed Schmidt, NEEP (moderator); Margaret Song, CLC; Sarah Eckstein, NEEP; and Gabe Arnold, Efficiency Vermont

Margaret Song of Cape Light Compact (CLC), which provides energy-efficiency programs for 200,000 customers in Massachusetts, said that the characteristics her organization looks for when considering lighting products include energy savings that are real and attributable, the ability to

track the data, customer acceptance of the product, savings versus cost, and the existence of market channels. She observed that while CLC's focus is on residential lighting, it's very important to coordinate with commercial lighting channels to ensure industry-wide progress. Song noted that CLC is increasing its goals for SSL and has volunteered to conduct an L PrizeSM field assessment in order to accelerate its own SSL learning process.

Sarah Eckstein of NEEP talked about the SSL Qualified Products List (QPL) maintained by the DesignLightsTM Consortium (DLC), a resource for high-quality, energy-efficient commercial lighting design and information in the Northeast. A major problem with SSL is that there are too many LED products on the market too soon, with too much attendant risk, which necessitates some kind of independent assurance of quality and performance. Eckstein explained that the QPL provides customers and energy program managers with such assurance and at present covers products in 10 application categories. To date, the QPL is used in 27 states and two Canadian provinces.

A sample page from the DesignLights Consortium's SSL Qualified Products List

| ENERGY STAR [®] Qualified Commercial LED Lighting | | | | | | | | | |
|--|------------------------|----------------------------------|----------------------------------|---------|-----------------------|------------------------|----------------------------|----------------|--|
| Manufacturer Name | Brand | Model | Luminaire Efficacy (lumens/Watt) | Wattage | Light Output (lumens) | Rated Lifetime (hours) | Color Temperature (Kelvin) | Date Qualified | |
| | REVIA | 7DR3-35K-DL | 40.0 | 28 | 1132 | 35,000 | 3000 | 09/17/09 | |
| | REVIA | 7DR3-41K-DL | 39.8 | 28 | 1120 | 35,000 | 4000 | 09/17/09 | |
| | REVIA | 7DS3-35K-DL | 38.3 | 28 | 1085 | 35,000 | 3600 | 08/14/09 | |
| | REVIA | 7DS3-41K-DL | 42.3 | 28 | 1191 | 35,000 | 4000 | 08/14/09 | |
| | Solia | 4DR4-27K-S-MD | 40.0 | 12 | 474 | 35,000 | 2700 | 12/10/09 | |
| | Solia | 4DR4-30K-S-MD | 43.8 | 11 | 468 | 35,000 | 3000 | 11/03/09 | |
| | Solia | 4DR4-35K-S-MD | 45.8 | 11 | 494 | 35,000 | 3600 | 11/02/09 | |
| | Solia | 4DR4-41K-S-MD | 47.7 | 12 | 576 | 35,000 | 4000 | 12/10/09 | |
| | Solia | 4DR5-41K-S-MD | 42.6 | 17 | 722 | 35,000 | 4000 | 01/15/10 | |
| | Solia | 4DS4-27K-DL | 35.1 | 12 | 412 | 35,000 | 2700 | 12/10/09 | |
| | Solia | 4DS4-30K-DL | 39.2 | 12 | 459 | 35,000 | 3000 | 12/10/09 | |
| | Solia | 4DS4-35K-DL | 39.7 | 12 | 475 | 35,000 | 3600 | 12/10/09 | |
| | Solia | 4DS4-41K-DL | 44.3 | 12 | 533 | 35,000 | 4000 | 12/10/09 | |
| | Solia | 4DS5-41K-S-MD | 38.5 | 17 | 651 | 35,000 | 4000 | 01/14/10 | |
| | Solia | 6DR4-30K-S-MD | 45.3 | 23 | 1062 | 35,000 | 3000 | 01/11/10 | |
| Surface/Pendant-Mounted Downlights (ENERGY STAR) | | | | | | | | | |
| EEMA Lighting Group | Litco | LPLED3L17 | 33.9 | 10 | 346 | 35,000 | 3000 | 12/11/09 | |
| Philips Solid-State Lighting Solutions, Inc. | Philips Color Kinetics | eW Downlight Powercore 65° 2700K | 35.2 | 15 | 528 | 35,000 | 2700 | 08/03/09 | |
| | Philips Color Kinetics | eW Downlight Powercore 65° 4000K | 35.3 | 15 | 526 | 35,000 | 4000 | 08/04/09 | |
| Outdoor Pole/Arm-Mounted Parking or Roadway Fixtures (DesignLights) | | | | | | | | | |
| BetaLED | LEDway Street Light | BLD-STR-T2HT-025-LED-B | 53.0 | 59 | 3108 | 117,000 | 6500 | 08/03/09 | |
| Lighting Science Group | Prolific RoadWay | LSR4 CW R2 2B | 80.5 | 146 | 11716 | 60,000 | 5000 | 03/12/10 | |
| | Shoe box | ShB CW CLR | 79.8 | 85 | 6765 | 60,000 | 6145 | 03/12/10 | |
| Philips Lumec | | GPLM-150W8LED4K-LE2 | 55.9 | 205 | 11447 | 70,000 | 4000 | 03/12/10 | |
| Philips Lumec | | GPLM-150W8LED4K-LE3 | 55.0 | 204 | 11220 | 70,000 | 4000 | 03/12/10 | |
| Philips Lumec | | GPLM-180W8LED4K-LE4 | 55.0 | 204 | 11281 | 70,000 | 4000 | 03/12/10 | |
| Philips Lumec | | GPLM-180W8LED4K-LEH2 | 56.2 | 205 | 11505 | 70,000 | 4000 | 03/12/10 | |
| Philips Lumec | | GPLS-200W8LED4K-LE2 | 58.0 | 102 | 5858 | 70,000 | 4000 | 03/12/10 | |

Gabe Arnold of Efficiency Vermont noted the increase in the number of commercial LED lighting products rebated in that state, from 497 in 2008 to 2,188 so far in 2010. He emphasized that the corresponding increase in energy savings (from 73 megawatt-hours to 603 MWh) is a drop in the bucket compared with his organization's 2010 goal of saving 36,000 MWh. He predicted that LED lighting will start to play a much more significant role in 2011, with the advent of more eligible products, enhanced incentives, new marketing and education efforts, and targeted initiatives. Arnold cited PAR and MR integral lamps, outdoor and sign lighting, downlights, and refrigerated case lighting as near-term SSL opportunities.

Question-and-Answer Session

Arnold was asked what "real, attributable energy savings" means. Arnold explained that Efficiency Vermont is beholden to state regulators, who verify that all the energy savings claimed for products rebated by the organization are true and accurate. Another question was asked about plans for nationwide visibility for rebates, to which Song replied that for national exposure, her organization relies on ENERGY STAR[®]. When it was pointed out that the "Smart Grid" initiative to put energy meters on homes is not widespread, Schmidt replied that "Many states are trying to do things with yesterday's policies and models. We need to change the way we regulate and administer policies."

5. Performance Issues

The third panel of the workshop focused on SSL reliability and performance issues. Moderator Eric Richman of PNNL spoke about reliability and current standards for measurement, observing that the potential long life of LEDs requires that not only the lamp, but all components of the luminaire be taken into consideration when determining lifetime. After reviewing existing LED lighting standards, he discussed the status of several still in development, including:

- IES standards for lumen maintenance of LED lamps and luminaires
- National Electrical Manufacturers Association (NEMA) standards on dimming (LSD 49), drivers (SSL-1 Driver), and module integration (LSD 45)
- Institute of Electrical and Electronics Engineers (IEEE) standard on flicker mitigation (PAR 1789)
- A color metric from the International Commission on Illumination (CIE TC1-69 – Color Quality Scale).

Fred Welsh of Radcliffe Advisors reported on the progress of the SSL Quality Advocates initiative, which is a joint effort between DOE and the Next Generation Lighting Industry Alliance (NGLIA). Welsh discussed the first edition of *LED Luminaire Lifetime: Recommendations for Testing and Reporting*, published in May 2010 by a working group under the guidance of the SSL Quality Advocates oversight committee. He noted that the recommendations advocate a system reliability approach, and that they recognize that both lumen maintenance lifetime¹ and electrical failure lifetime² are important components of SSL lifetime.

Howard Wolfman of Lumispec Consulting discussed the development of SSL dimming standards. He noted that there is a compatibility problem between SSL luminaires and dimmers, especially in the residential sector, with users reporting poor dimming performance, even with dimmers that are specified by luminaire manufacturers. Wolfman said the ideal standard would ensure that all compliant dimmers and drivers would deliver good dimming performance when paired. He described the ongoing efforts by NEMA and the American National Standards Institute (ANSI) to create such standards.

¹ Lumen maintenance lifetime is typically defined as the estimated time for luminous flux to fall below 30 percent of the initial value.

² Electrical failure lifetime refers to the point in time when some fraction of a luminaire population has experienced lights-out failure.

Question-and-Answer Session

Wolfman was asked to elaborate on damage to dimmers. He said such damage could be from current conditions and is not always immediately apparent, e.g., dimmer life can be shortened due to overheating. Another question was asked as to why L₇₀ as a metric for lumen maintenance is product-specific rather than category-specific? Welsh said it would be impossible to come up

An attendee questions members of Panel 3 (from left): moderator Eric Richman, PNNL; Fred Welsh, Radcliffe Advisors; and Howard Wolfman, Lumispec Consulting



with an L₇₀ figure for a product category and explained that as currently used, L₇₀ is a “floor” below which a product’s light output should not fall and that it is generally measured from the peak lumen output rather than the initial output. A third question asked how to communicate lifetime to the end-user? Welsh said what counts is the luminaire’s lifetime, which has other components than just the LEDs.

6. Recognition for Lighting Facts® Partners



DOE Portfolio Manager Jim Brodrick (far left) recognized Lighting Facts partner companies for their commitment to rigorous product evaluation. Accepting on behalf of the honored Partners are (from left): Chris Andrew, Renaissance Lighting; Keith Cook, Philips; Bill Hamilton, The Home Depot; Tom Harold, Grainger; Collin Cremona, Costco Wholesale; Brian Owen, greenTbiz; Patrick O’Flaherty, Cree; and Carina Betts, CRS.

Nine Lighting Facts partners received special recognition for demonstrating their ongoing commitment to the Lighting Facts program and to product evaluation. Brodrick applauded the nine for going “above and beyond” to integrate Lighting Facts into their everyday business practices. The nine partners recognized were Cree, CRS, Philips, Renaissance Lighting,

The Home Depot, Costco Wholesale, Grainger, Lightswitch Architectural, and greenTbiz. Representatives from each partner company received a Lighting Facts digital widget for the company's website as a tool for highlighting their commitment to product quality as well as a gesture of DOE's appreciation. These partner companies will also be profiled on the Lighting Facts website.

7. Lessons from the Field

7.1 Lessons Learned

Panel 4 of the workshop focused on lessons learned from recent real-world installations of LED lighting products, touching on product design, installation issues, dimming, flicker, and lifetime. The panel was moderated by Bruce Kinzey of PNNL, who manages DOE's GATEWAY Demonstration Program.

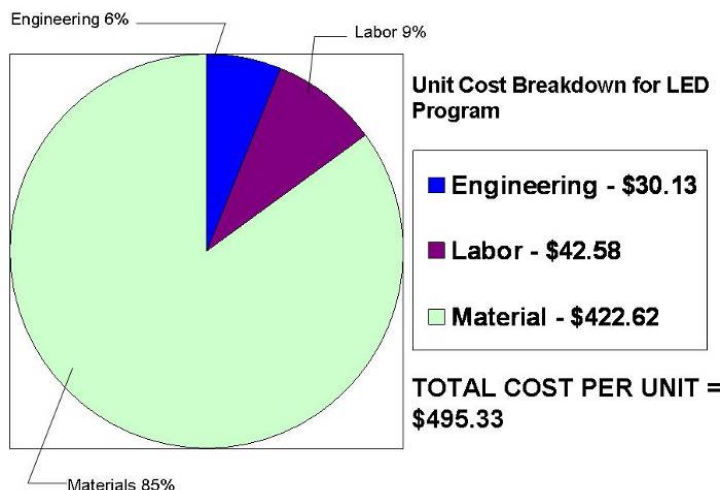
Harry Hobbs of InterContinental San Francisco described a GATEWAY demonstration project in which switching to LED replacement lamps satisfied that hotel's high standards for appearance and functionality while saving energy. He described the selection criteria for the lamps, as well as the rigorous testing process for submitted products. Hobbs reviewed problems encountered, such as inflated performance claims, dimming issues, and incompatibility with electronic transformers. Cautioning that the cheapest LED products are not necessarily the best, he advised comparing samples with incumbent lamps in hands-on mockups, testing in the actual fixtures for at least a week, and getting a three-year warranty for light output and color stability.



A comparison of LED and halogen products for the same application at the InterContinental San Francisco hotel

Ed Ebrahimian of The City of Los Angeles described his city’s experience with selecting and installing LED street lighting to replace the incumbent technology, which primarily consists of high-pressure sodium (HPS). He explained that 20,000 LED street lights are already installed, with another 120,000 to be installed over the next four years. Ebrahimian noted that not all manufacturer claims are true. He also observed that the change from HPS to LED luminaires not only improved visibility, but was perceived by end-users to significantly increase lighting levels, even though this was not actually the case. Ebrahimian said the LED luminaires have better uniformity than HPS, bring energy savings of 55 percent, and have garnered mostly positive feedback.

Cost breakdown for LED street lighting in The City of Los Angeles



Lighting designer Frank Florentine described a project installing LED lighting in a 5,000-square-foot gallery in the Steven F. Udvar-Hazy Center (National Air and Space Museum) to replace the incumbent standard mercury units. He reviewed the advantages of LED fixtures in that setting, including energy efficiency, ease of installation, lighter weight, a multi-tap ballast, and instant on and off. Florentine noted that the energy savings from switching to SSL ranged from 76 percent for 2-x-2' drop-ins to 40 percent for PAR 36 and track lighting, with less ultraviolet light emitted and higher illumination levels.



An attendee questions members of Panel 4 (from left): moderator Bruce Kinzey, PNNL; Harry Hobbs, InterContinental San Francisco; Ed Ebrahimian, The City of Los Angeles; Lighting designer Frank Florentine

Question-and-Answer Session

Ebrahimian was asked about utilizing remote dimming, and he said Los Angeles has plans to install within the next several months dimmable fixtures or drivers that can be controlled by remote monitoring units. “It’s an opportunity we don’t want to miss,” he said. Hobbs was asked

what kinds of utility programs make it worthwhile for InterContinental San Francisco to try out different technologies. He cited several Pacific Gas and Electric programs, including New Efficiency Options and Non Residential Retrofit, as being very helpful. Asked about the potential for LEDs to degrade objects that are sensitive to light, Florentine said there was a controversy about that, but he noted that products that emit light primarily in a narrow band of the spectrum can cause damage, but that LEDs have the potential to be full-spectrum products and thus shouldn't have a problem. "In the museum world, you look at the quantity and quality of the light," he said.

7.2 Reception

Day 1 concluded with a reception sponsored by Connecticut Energy Fund, which provided additional opportunities for attendees to talk with panelists, ask questions, and build relationships. Attendees valued the time set aside to discuss SSL market advances and challenges with their peers.



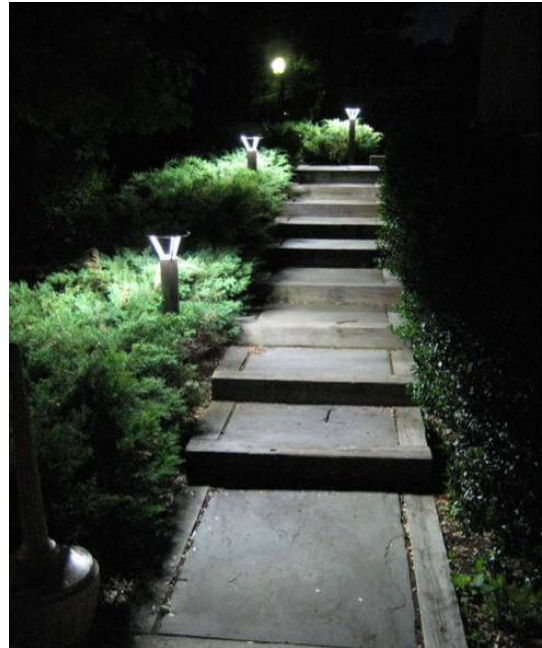
On Wednesday evening, participants networked at a reception sponsored by Connecticut Energy Fund.

8. Solid-State Lighting in Higher Education

Day 2 of the workshop began with a panel on issues and recommendations that had surfaced at a recent DOE workshop on SSL in higher-education facilities, including barriers to adoption, where LED products work best on campus, and how to avoid the pitfalls.

Jean Stark of JMZ Architects and Planners reviewed the size and diversity of the higher-education market, as well as the enormous range of different lighting applications typically found on college campuses, e.g., classrooms, laboratories, lecture halls, conference rooms, offices, theaters and concert halls, libraries, student centers, residence halls, childcare centers, galleries and displays, animal facilities, dining halls, retail space, recreation facilities, athletic facilities, and campus service spaces. She discussed the different lighting requirements of the various college segments, including the administration, the faculty, the students, and the facilities personnel.

Lighting designer Sandra Stashik of Grenald Waldron Associates reviewed key criteria for exterior campus lighting, including vertical and horizontal illuminance, glare, luminance, visual hierarchies, color characteristics, energy usage, sustainability and carbon footprint, ease of maintenance, and first cost versus payback. She gave examples of some of the problems her firm has encountered implementing SSL in higher-education projects and presented potential best practices for use of LED lighting in campus applications. Stashik stressed the difference between light quality and light quantity, and identified water, temperature, connectors, and short lifetime as potential SSL failure issues.



LED lighting tested on the campus of Princeton University

Panel moderator Naomi Miller of PNNL reviewed key recommendations that emerged from the recent DOE workshop on SSL in higher education, in which manufacturers of LED luminaires, components, and controls as well as facility managers, engineers, and lighting designers focused on identifying ways to change SSL product design in order to improve quality, functionality, and sustainability. Among the recommendations were that electricians should get specialized training in SSL to ensure that LED products are installed properly, that luminaire manufacturers should take responsibility for all components, and that LED luminaires should be designed to signal when their light output degrades below a certain point.

Question-and-Answer Session

An attendee asked whether the desire for standardized products is compatible with trying new things, to which Stark replied with an emphatic “yes!” Stashik added that, for example, campuses would love to see outdoor lighting products that need less maintenance than existing products. Another attendee questioned whether colleges and universities will consider products that aren’t easily serviced. Stashik agreed, pointing out that buyers are wary of products that entail difficult service or repair. To a question about what foot-candle levels are used in street lighting projects, Stashik replied that they vary, depending on the setting.

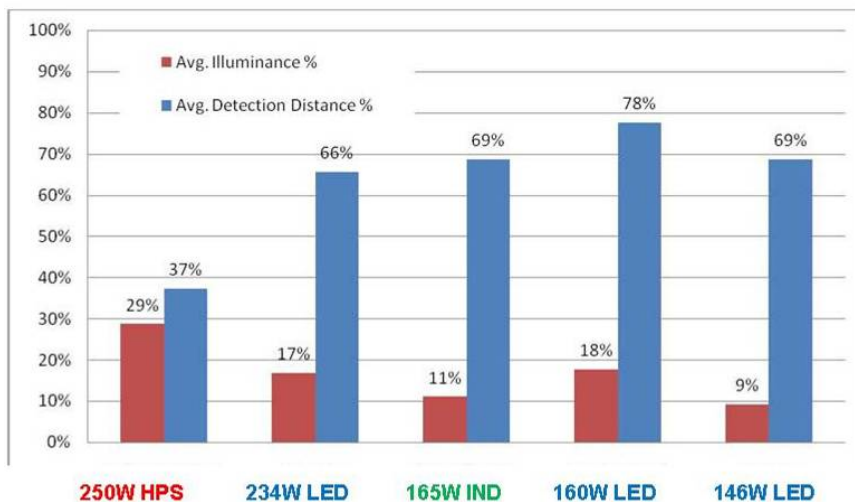


An attendee questions members of Panel 5 (from left): moderator Naomi Miller, PNNL; Jean Stark, JMZ Architects and Planners; Sandra Stashik, Grenald Waldron Associates

9. Light at Night

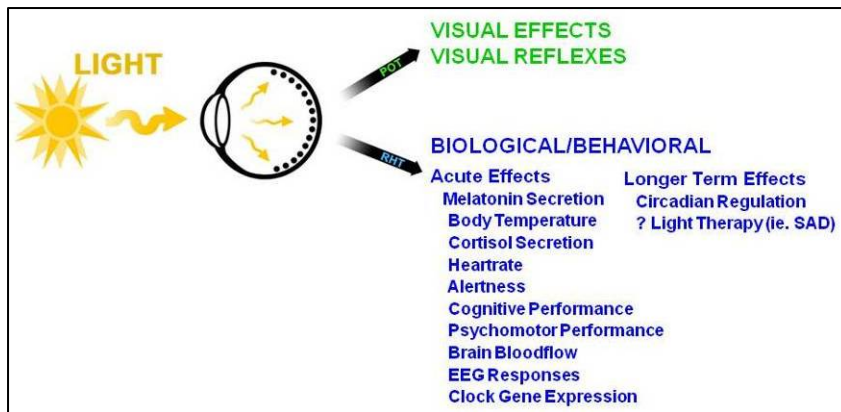
Panel 6 focused on what we know and don't know about the possible health implications of exposure to light at night. The panel was moderated by Jason Tuenge of PNNL, who set the stage by reviewing the advantages of LEDs over other lighting technologies with regard to nighttime light exposure, including energy savings, greater spatial and temporal control, and improved color contrast. He noted that the efficacy of LED luminaires typically improves as the correlated color temperature (CCT) increases (i.e., as the light's blue content increases), so that restricting the blue content would decrease the energy savings. He explained that the goal of the panel is to get guidance from the panelists on how to responsibly use SSL technology for both outdoor and indoor applications.

Ronald Gibbons of Virginia Tech Transportation Institute discussed his research on the visual effects of broad-spectrum roadway lighting, including LED luminaires. He explained that because the human eye is more sensitive to broad-spectrum (i.e., bluer) light sources in outdoor environments at night, and because these sources can also provide more color contrast than those with lower CCTs, there is the potential to increase lighting performance by broadening the spectrum. He reviewed three different studies that indicated improved visual performance with broad-spectrum street lighting compared with high-pressure sodium (HPS), even when the broad-spectrum illuminance levels were lower. Gibbons also noted that increased sky glow is a potential side-effect of increased visibility under broad-spectrum sources.



Results of a study of how far away objects could be detected under LED, HPS, and induction street lighting, where average illuminance versus detection distance was measured as a percentage of 400W HPS

George Brainard of Jefferson Medical College discussed his research on the non-visual effects of light on humans. He explained that photoreceptors in the human eye play a key role in regulating the body's circadian (daily) cycles and are especially sensitive to light in the blue range. Brainard indicated that excessive exposure to light at night can suppress the body's production of the sleep-inducing hormone melatonin, thus interfering with sleep and various biological processes. He said more research is needed on the degree of exposure necessary to produce this effect and noted that there may prove to be other negative health effects of nighttime light exposure (e.g., breast cancer), as well as therapeutic benefits of light (e.g., in treating winter depression). Brainard concluded that whereas daytime lighting should be brighter, nighttime lighting should be as dim as possible, and both should have spectra designed to optimally balance energy efficiency with visual and non-visual needs.



In addition to its role in vision, light entering the human eye has a wide range of other biological and behavioral effects.

Mariana Figueiro of Rensselaer Polytechnic Institute reviewed research that illustrates the uncertainties about the possible health effects of exposure to light at night. She discussed a recent study in which her team found that nurses working a day shift were better synchronized with the natural daylight cycle than their rotating-shift counterparts in terms of activity levels and light exposures. Figueiro also described an ongoing study to investigate a hypothesized link between sky glow and breast cancer rates for women in urban areas, and noted that while no firm conclusions can be drawn at this point, it appears urban dwellers are exposed to negligible amounts of light while sleeping. Last, she summarized findings from another recent study in which her team estimated melatonin suppression caused by various types of light sources in typical outdoor installations. While the higher-CCT sources were predicted to increase melatonin suppression, the effects for realistic exposure periods appeared to be quite small, and Figueiro reiterated that additional studies are needed.

Question-and-Answer Session

An attendee questioned whether a distinction should be made between outdoor and indoor nighttime light exposure? “My personal feeling is that in some cases, we may be exposed to too little light in the day and too much at night,” Figueiro said. “If you’re exposed to very low light levels during the day, you may be more sensitive at night.” Brainard added that the important point is a person’s light exposure during a 24-hour period. “You can’t just look at one time period during the day,” he said. Another question was whether there are any recommendations for the right color temperature for LED outdoor lighting, to which Gibbons replied that there

seem to be regional preferences, with northern cities preferring cooler temperatures and cities further south preferring lower CCTs.

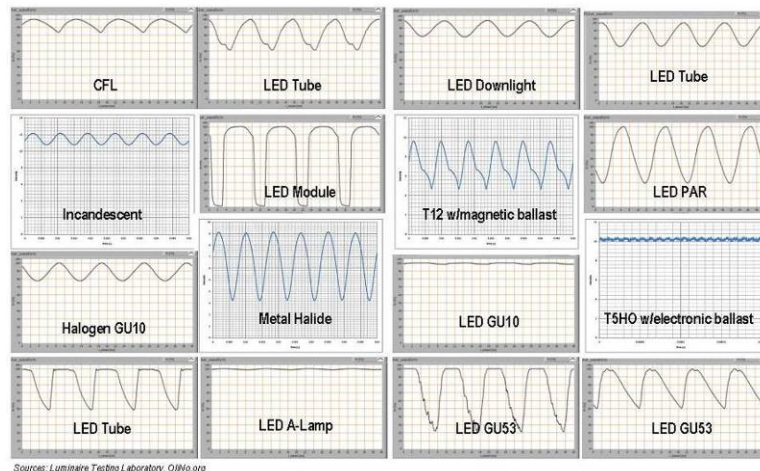


Panel 6 (from left): moderator Jason Tuenge, PNNL; Ronald Gibbons, Virginia Tech Transportation Institute; George Brainard, Jefferson Medical College; Mariana Figueiro, Rensselaer Polytechnic Institute

10. Possible Effects of Flicker

Panel 7 explored the issue of flicker and its possible effects on health and visual comfort. Moderator Michael Poplawski of PNNL set the stage for the other panelists, giving the background and pointing out that every light source has some kind of modulation.

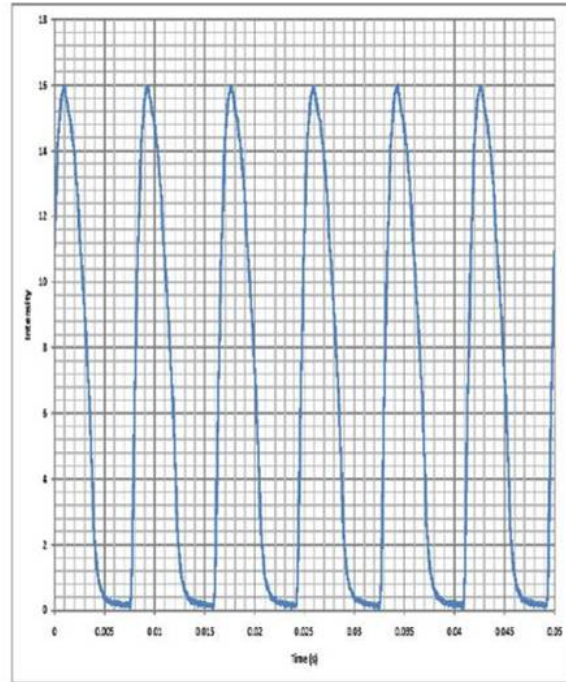
All light sources have some degree of modulation.



Jennifer Veitch of the National Research Council of Canada's Institute for Research in Construction observed that the brain detects some of this modulation, even though it's not perceived, and that such unperceived flicker has been shown to disrupt eye movements across text. She noted that flicker can also cause headache and eyestrain, that some effects of flicker are not immediate, and that younger people appear to be more at risk than older ones. Veitch explained that in addition to frequency, the depth of the modulation, and possibly its shape, determine flicker's effects. "Paying attention to flicker while designing the next generation of SSL is one piece of the puzzle in ensuring that it is widely accepted and successful," she concluded.

Kevin Willmorth of Lumenique discussed questions of modulation in the context of lighting and product design. He made the points that LED flicker is not an AC or DC issue, and that frequency alone doesn't provide an effective basis for any standard in isolation, because defining the modulation is also critical. "Our metrics really aren't working to describe what we're seeing and what we're perceiving," he said. Willmorth noted that studies of the effects of flicker are limited in number and that many of them are decades old. He emphasized that the effects of dimming should be included in any discussion of LED flicker and said the industry needs design guidance about flicker for end-use application and product development.

The flicker pattern of a highly modulated LED array appears significantly different from conventional sources, prompting the question: Is this acceptable modulation?



Data Source: Michael Grather, Luminaire Testing Laboratory

Brad Lehman of Northeastern University, who chairs the IEEE PAR 1789 Committee, discussed their work in developing recommended practices for the design of LED driving systems to modulate at safe frequencies for their particular applications, in order to protect against such health risks as headaches, eyestrain, and epileptic seizure. He noted that these health risks have been identified as being associated with low-frequency modulation of high-brightness LEDs. Lehman observed that unlike other lighting technologies, LEDs respond instantaneously to the electric current, resulting in no "filtering" of the flicker through time delay.

Question-and-Answer Session

An attendee made the point that it will be very difficult to achieve widespread market adoption for SSL when there are so many issues to overcome in addition to cost such as flicker, lifetime, size, and dimming. Willmorth noted that mistakes that are made by the industry at this early stage will have a big impact on market adoption. "Now is the time to ... come up with the



Panelists (from left) Michael Poplawski, PNNL (moderator); Jennifer Veitch, National Research Council of Canada; Kevin Willmorth, Lumenique; Brad Lehman, Northeastern University

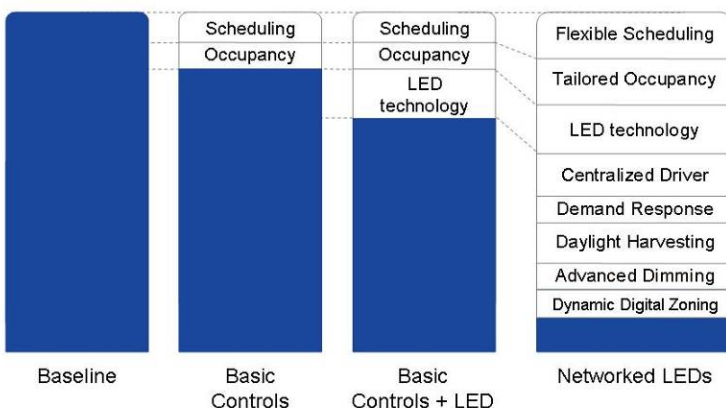
recommended practices to avoid those issues and problems,” he said. In response to a question as to whether there will be guidelines on what kinds of modulation depth are acceptable, Veitch said that is definitely a goal. “We know frequency is an issue, but we think depth is also an issue,” she said.

11. A Look Ahead

Panel 8 explored where LED performance is projected to head, what new lighting product form factors are emerging, and how the development of SSL is enabling companies to think differently about the way lighting is delivered as a system. Moderator Kelly Gordon of PNNL reviewed the progress that has been made to date in terms of LED luminaire performance, as well as performance projections for the near future. She also noted that it is important to “think outside the box” in terms of how light is delivered to spaces and tasks, when the lights are on and at what levels, where the light goes, and even how the lights are powered.

Makarand Chipalkatti of OSRAM SYLVANIA described how SSL is creating a new paradigm for lighting, with the potential for such features as control systems to cycle lights automatically, furniture that incorporates light-emitting fibers, and special on-demand lighting to accent hair or dress colors. He reviewed the key elements that will accelerate the adoption of SSL. These, Chipalkatti said, include evolution (change and constant modification), flexibility (e.g., simple plug-and-play designs that have a clear path to minimal-cost upgrading), conversion of incumbent technology to SSL, interoperability (design standardization of key elements of the system), and infrastructure (e.g., DC power distribution).

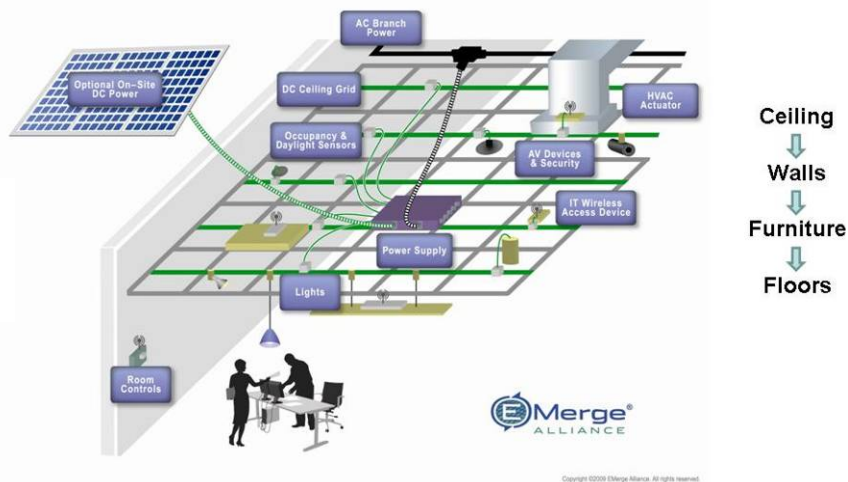
Jeremy Stieglitz of Redwood Systems described a new method his company is developing to power LEDs, which amounts to a unified DC power and communications system architecture. He explained that the new architecture centralizes the LED drivers, which results in better performance, added intelligence, drive flexibility, better dimming, and easier installation. Stieglitz noted that communication takes place on the same power infrastructure, which makes for a rich and robust sensor and control platform, facilitates multiple sensors and per-light knowledge, and simplifies specification, installation, and troubleshooting. He said the new system has the potential to leverage power, sensors, and communications for all “smart building” needs.



The potential energy savings from a unified DC power and communications system architecture is substantial.

Karen Lee of EMerge Alliance described a hybrid AC/DC power platform for use in commercial buildings, which integrates interior infrastructures, power, controls, and peripheral devices. She said such a platform reduces energy consumption by 30 percent, requires 15 percent less capital than present platforms, and is twice as reliable. Lee explained that low voltage at the user interface enables plug-and-play device flexibility and that the system facilitates energy savings from efficient lighting, controls, and other electrical devices in addition to allowing direct integration of site-based renewable energy sources. She described how EMerge Alliance is developing an open standard for such a platform and discussed several demonstration sites using the platform.

A typical configuration of the hybrid AC/DC power platform advocated by EMerge Alliance



Question-and-Answer Session

Lee was asked what kind of time horizon she anticipates for seeing greater penetration of EMerge Alliance’s approach. She noted that the standard was just approved and said she hopes it will take less than five years. Added Chipalkatti: “I think people will adopt it very fast if they see great value in it, so it’s a question of developing the value.” Someone else asked what the panelists would propose to make the systems they described easy to install, without having to do too much educating. Stieglitz said that is the essence of the problem and noted that the Internet took off when it moved from “tribal” (i.e., understood by only a few) to “simple” (i.e., understood by everyone). He said the goal is for the new system to work in such a way that “the user plugs it in and it works.”

12. Conclusion

Brodrick concluded the two-day workshop by thanking participants for their input and participation. He noted that the next DOE SSL workshop is in February 2011 — the eighth annual Solid-State Lighting R&D Workshop — and also encouraged attendees to stay apprised of DOE SSL program activities by visiting www.ssl.energy.gov.

Presentations and materials from DOE’s fifth annual SSL Market Introduction Workshop are posted online at www.ssl.energy.gov/philadelphia2010_materials.html.

13. APPENDIX: 2010 SSL Market Introduction Workshop Participants

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