Workshop Report

Lighting Research and Development

Building Technologies Program

Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

September 2007

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government, nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency contractor or subcontractor thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United Sates Government or any agency thereof.

COPIES OF THIS REPORT

Electronic (PDF) copies of this report are available to the public from:

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Building Technologies Program
Solid-State Lighting Research and Development Portfolio
http://www.netl.doe.gov/ssl

ACKNOWLEDGEMENTS

The Department of Energy would like to acknowledge and thank all the participants for their valuable input and guidance provided during the July 2007 DOE SSL Market Introduction Workshop. The Department would also like to thank all the direct contributors and especially the following individuals:

Vrinda Bhandarkar, Strategies Unlimited
James Brodrick, U.S. Department of Energy
Robert Cilic, Osram Sylvania
Kevin Dowling, Color Kinetics
Kelly Gordon, Pacific Northwest National Laboratory
Bruce Kinzey, Pacific Northwest National Laboratory
Sergio Mazon, Osram Sylvania
Jeff McCullough, Pacific Northwest National Laboratory
Mark Michalski, New York State Research and Development Authority
Priscilla Richards, New York State Research and Development Authority
Eric Richman, Pacific Northwest National Laboratory
Linda Sandahl, Pacific Northwest National Laboratory
Ed Schmidt, Northeast Energy Efficiency Partnerships
Sameer Sodhi, Osram Sylvania
Marsha Walton, New York State Research and Development Authority
Fred Welsh, Radcliffe Advisors

This report was prepared for the U.S. Department of Energy and the National Energy Technology Laboratory by Akoya under NETL Order Number: DE-AD26-03NT30656.

COMMENTS

The Department of Energy is interested in feedback or comments on the materials presented in this Workshop Report. Please write directly to James Brodrick, Lighting R&D Manager:

James R. Brodrick, Ph.D.
Lighting R&D Manager
EE-2J/Forrestal Building
U.S. Department of Energy
1000 Independence Avenue SW
Washington, DC 20585-0121

TABLE OF CONTENTS

1. Introduction 1
2. SSL Challenges and Goals 3
2.1 Welcome and Overview 3
2.2 SSL Essentials: Technology, Applications, Advantages, Disadvantages ... 3
2.3 Lessons Learned from CFL Market Introduction 5
3. DOE SSL Program Overview and Commercialization Support Plan 7
3.1 DOE Solid-State Lighting Program Overview 7
3.2 2007 Lighting for Tomorrow Design Competition 9
3.3 DOE Technology Demonstrations 12
3.4 DOE SSL Commercial Product Testing Program 13
3.5 ENERGY STAR for SSL 15
3.6 LED Standards and Test Methods Development 16
4. Breakout Sessions: SSL Product Case Studies 17
4.1 Integrated SSL Table Lamp 17
4.2 Commercial Office OLED Ceiling Light 19
4.3 Recessed-Can Light Fixture for Residential Use 22
4.4 Outdoor Walkway and Streetscape Lighting System 26
4.5 LED Spotlight for Retail Store Lighting 30
5. Tour of Osram Sylvania's LIGHTPOINT® Institute for Lighting Technology . 34
6. Market Perspective on SSL 35
7. New York State Research and Development Authority Activities in SSL 37
8. Next Steps 39
9. Appendices 41
APPENDIX A: Workshop Attendees 42
APPENDIX B: DOE SSL Program Fact Sheets 46
APPENDIX C: DOE SSL Commercialization Support Plan Draft 51
APPENDIX D: Case Studies 1-5 80
APPENDIX E: Index of Acronyms 106

LIST OF FIGURES

Figure 2-1: DOE Lab to Market Strategy 3
Figure 3-1: DOE Lab to Market Strategy and Partners. 7
Figure 3-2: Comparison of System Efficacy and Luminaire Efficacy.. 15
Figure 6-1: 2006 Market by Application 35
Figure 6-2: Forecast for LEDs in Lighting Market 36

1. Introduction

Northeast Energy Efficiency Partnerships, Inc.

More than 100 attendees gathered in Boston, Massachusetts to participate in the "Voices for SSL Efficiency" Solid-State Lighting Workshop on July 16-17, 2007. The workshop, hosted by the U.S. Department of Energy (DOE) and Northeast Energy Efficiency Partnerships (NEEP), was the second DOE meeting to explore how Federal, State, and private-sector organizations can work together to guide market introduction of high-performance SSL products. The first workshop, hosted by DOE and Southern California Edison, was held in Pasadena in April 2007. In both workshops, a diverse gathering of participants—energy efficiency organizations, utilities, government, and industry—shared insights, ideas, and updates on the rapidly evolving SSL market.

James Brodrick, DOE SSL Portfolio Manager, and Ed Schmidt, Director of Regional Initiatives at NEEP, welcomed attendees and invited them to join forces to leverage resources and shape markets for high-performance SSL products.

Pictured, left to right: Ed Schmidt, NEEP Director of Regional Initiatives and James Brodrick, DOE SSL Portfolio Manager.

Chapter 2 of this report looks at SSL challenges and goals. James Brodrick described DOE's national strategy to push SSL technology and the market to the highest efficiency and the highest lighting quality, emphasizing opportunities to partner and participate in DOE activities. Kevin Dowling of Color Kinetics offered an overview of SSL technology, discussing the technology status, advantages and disadvantages, current applications, and future potential. Linda Sandahl of Pacific Northwest National Laboratory (PNNL) highlighted key findings from the DOE report, *Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market*.

Chapter 3 outlines DOE's strategy to support market introduction of SSL. James Brodrick provided an overview of the DOE SSL Commercialization Support Plan, followed by a closer look at key elements:

- Design competitions, such as Lighting for Tomorrow
- Technology demonstrations
- Product testing
- ENERGY STAR® criteria for SSL
- LED standards and test method development

Chapter 4 details breakout sessions, in which attendees explore case studies based on hypothetical SSL products, developing a marketing strategy for each product and identifying which DOE plan elements support this strategy. Chapter 5 describes the tour of Osram Sylvania's LIGHTPOINT Institute for Lighting Technology, where attendees could touch and see how interactive demonstration units and training aids are used for live, classroom-based training.

Chapter 6 covers Vrinda Bhandarkar of Strategies Unlimited's analysis of the high-brightness LED market for lighting. Chapter 7 summarizes the New York State Research and Development Authority (NYSERDA) activities in SSL, given by Priscilla Richards, Marsha Walton, and Mark Michalski. Chapter 8 details next steps for DOE market introduction activities.

All workshop materials and reports referenced in this document can be found on the DOE SSL website at:
http://www.netl.doe.gov/ssl/PDFs/Boston_2007/materials.html.

2. SSL Challenges and Goals

2.1 Welcome and Overview

James Brodrick, U.S. Department of Energy

James Brodrick kicked off the workshop by highlighting recent developments in SSL, including significant efficacy breakthroughs and commitments from early adopters—like Wal-Mart and the California Home Builders—that encourage widespread use of SSL.

The unique attributes of SSL will lead to new forms and functions for lighting, and trigger fundamental changes in the lighting industry value chain and how lighting is delivered to the market. Brodrick emphasized that the transition to SSL will require coordinated industry-wide solutions that leverage key market-introduction partner channels.

DOE has developed a comprehensive national strategy to push SSL technology and the market to the highest efficiency and the highest lighting quality. DOE's lab-to-market strategy draws on key partnerships with the SSL industry, research community, standards setting organizations, energy efficiency groups, utilities, and others, as well as lessons learned from the past. The Department's support acts as a catalyst from end to end, and key partnerships guide DOE planning every step of the way.

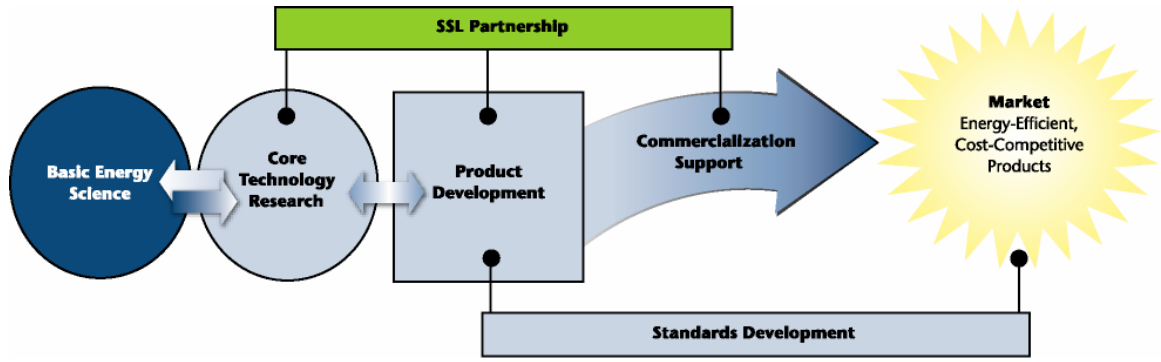


Figure 2-1: DOE Lab to Market Strategy

"The market challenges we face are complex, and DOE is stepping up to the challenge—focusing its resources in strategic areas that foster the growing market for high performance, high efficiency SSL products," Brodrick concluded. "You [the workshop participants] have an opportunity to partner with DOE and others, and join in the evolution of the U.S. lighting industry."

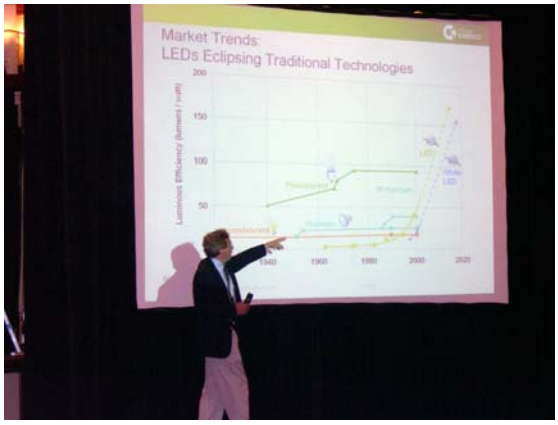
2.2 SSL Essentials: Technology, Applications, Advantages, Disadvantages

Kevin Dowling, Color Kinetics

Kevin Dowling, Vice President of Innovation at Color Kinetics, began his presentation with a photograph of the Empire State Building, lit by LEDs. While the use of LEDs for

dramatic exterior illumination is becoming quite common, the real opportunity, said Dowling, lies *inside* the building. He estimated there are 100,000 lamps inside that building, representing a huge opportunity for white light LED manufacturers and for significant energy savings.

Dowling then described the evolving path of LED technology, from indicator lights to general illumination. “The first car with LED headlights is coming out in the next model year,” Dowling said. Current applications include traffic lights, automotive applications, exit signs, portable appliances, cell phones, PDAs, signage, direct-view displays, and video screens. Emerging applications include transportation (marine, automobile, and aviation) and lighting niches. The future of LEDs, though, is in general illumination.



Kevin Dowling from Color Kinetics presented a broad overview of SSL technology, applications, advantages, and disadvantages.

He presented a graph on market trends, showing that LEDs are rapidly overcoming traditional lighting products in terms of luminous efficiency. Commercially available LEDs are four times more efficient than conventional incandescent and halogen sources, and there are already laboratory white LED sources that are 30% more efficient than linear fluorescent sources. Off-the-shelf LED sources are only 18-35% less efficient than compact and linear fluorescent sources today, and the gap is closing rapidly. “The trend is key,” said Dowling, “not the snapshot.”

Dowling described the anatomy of an intelligent LED lighting solution, which re-invents today’s lighting system with a complete solution that will set a new standard form-factor for LED systems. This re-invented system will impact the lighting industry value chain and trigger fundamental changes in design, manufacturing, sales, and distribution.

Dowling noted that SSL technology challenges—color temperature, efficacy, quality of light, thermal management—are currently being addressed. Costs will continue to drop due to manufacturing improvements and economies of scale. He outlined three key needs to enable mainstream adoption of SSL:

- Real efficacy parity (or better) with fluorescent sources
- Costs allowing two year or less return on investment (ROI)
- Standards for specifications

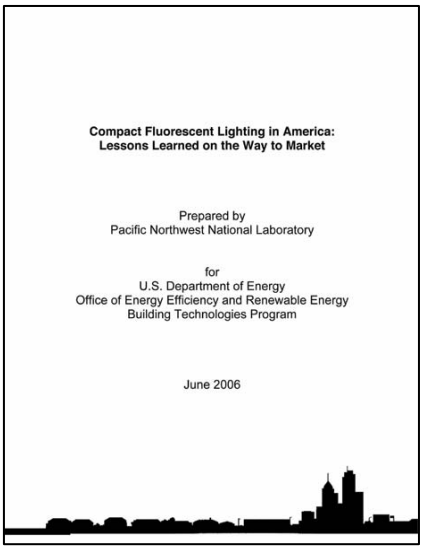
Dowling concluded by emphasizing the role of DOE in supporting market introduction of SSL. The Department is looking at the past to learn historical lessons. It is looking at the present, investing in new ideas, creating partnerships, sponsoring workshops that lead to roadmaps and investments, developing ENERGY STAR guidelines, and supporting and driving development of standards. Finally, DOE is looking to the future, implementing a series of targeted strategies to accelerate SSL adoption.

In the question and answer session following Dowling's presentation, one attendee asked if there are any disposal regulations for LEDs. Dowling answered that no needs are immediately apparent. Another participant inquired whether LEDs were going to have rated temperatures. Dowling replied that lumen depreciation increases with temperature; typically LEDs are rated for 85°C or over 100°C now. A third person asked if LED lamps are integrated, throw-away items; Dowling said that no systems featuring replacement lamps have been developed yet. "How do LEDs stand up to salt water?" someone inquired. The sealant, which is often an epoxy, degrades in humid conditions, so salt water definitely has adverse effects, Dowling said. One last audience member asked whether any studies of the environmental impact of the LED manufacturing process have been made. Dowling replied that LED manufacturing uses processes common to semiconductor fabrication plants. He is not aware of any studies that look specifically at the chain of environmental impact in the manufacture of LEDs.

2.3 Lessons Learned from CFL Market Introduction

Linda Sandahl, Pacific Northwest National Laboratory

Linda Sandahl of Pacific Northwest National Laboratory (PNNL) shared key findings from the DOE report, *Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market*. To download a PDF copy of the report, see: http://www.eere.energy.gov/buildings/info/documents/pdfs/cfl_lessons_learned_web.pdf.


Compact Fluorescent Lighting in America:
Lessons Learned on the Way to Market

Prepared by
Pacific Northwest National Laboratory

for
U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Building Technologies Program

June 2006

The report is based on a review of 45 previous studies and interviews with CFL manufacturers. Sandahl noted that the first CFLs were too big and heavy, and suffered from buzz and flicker, poor cold-weather performance, and poor color quality. The price of $35 per lamp was also a significant barrier to market entry. Early CFLs developed a bad reputation that was hard to overcome, even after the technology and price improved significantly.

According to the report, the technical problems with early CFLs were compounded by marketing problems:

- Some manufacturers exaggerated lifetime claims of up to 6,000 hours.
- Manufacturers provided inconsistent incandescent equivalency claims.

- Consumer awareness was hindered by lack of a common name (CFL, CSL, SL-Lamps, etc.).
- Efficiency programs used inconsistent specifications and names.
- Products were not available where people buy bulbs (traditionally supermarkets).
- Retailers did not understand the product.

Technical and marketing problems led to slow market adoption of CFL products. In 1990, CFLs captured only 0.2% of the national lighting market. In 2001, the West Coast electricity crisis prompted an increase to 2.1%. In California, for example, targeted efforts eventually increased the market share to 8.5% before it leveled off at 6%. New 2006 data showed that CFLs had achieved 32% market penetration in the Northwestern United States, whereas the nation as a whole reached only 5%. This amounts to an estimated 4.85 CFL bulbs per household in the Northwest. Sandahl noted that "sales are still far under their potential."

Sandahl cited 10 key lessons learned that apply to market introduction of SSL:

- Know and admit technology limitations.
- Identify technology advantages.
- Performance is more important than appearance.
- Work toward consistent, industry-wide terminology; identify and avoid terms with negative connotations.
- Focus on product value versus price.
- Target training programs/awareness campaigns to traditional market channels such as builders, designers, and retailers.
- Delay program launch rather than introduce inferior products; first impressions are long lasting.
- Join forces with others in national energy efficiency programs (e.g., ENERGY STAR). "ENERGY STAR has been amazingly successful for CFLs," Sandahl noted.
- Establish minimum performance requirements.
- Introduce new lighting technologies first in niche applications or markets where benefits are clearly defined and consistent with buyer needs.

"Early consumer experiences with fluorescent lamps and CFLs still define attitudes toward CFLs," Sandahl said in closing. "Let's get it right with LEDs, and learn from our past."

The brief discussion that followed the presentation started with one participant asking if DOE had done a study comparing CFL marketing to LED marketing. Sandahl replied that while no formal study has been done, the ongoing testing of LED products through DOE's testing program has revealed exaggerated performance claims by some manufacturers. The feedback these manufacturers receive from the DOE testing program should help them to correct any misstatements. Another attendee asked, "To what extent do you think disposal requirements for CFLs has limited their adoption?" Sandahl replied that many residential consumers seemed to ignore the disposal requirements and simply threw CFLs out with their regular garbage, so the requirements probably played a small role in limiting the technology's adoption.

3. DOE SSL Program Overview and Commercialization Support Plan

3.1 DOE Solid-State Lighting Program Overview

James Brodrick, U.S. Department of Energy

"DOE has a Congressional directive to support solid-state lighting research, development, and commercial application activities for the Federal government," James Brodrick said in his overview of the DOE SSL Portfolio, adding that the Department also has the plans, partners, and programs to carry out this directive.

Brodrick cited DOE's partnerships with the Next Generation Lighting Industry Alliance and the Illuminating Engineering Society of North America, as well as over 150 market-side partners and 18 Federal agency partners who are supporting deployment efforts. NEEP and the Consortium for Energy Efficiency (CEE) have been competitively selected as lead organizations to establish the DOE Technical Information Network. The purpose of the Network is to increase awareness of SSL technology, performance, and appropriate applications.

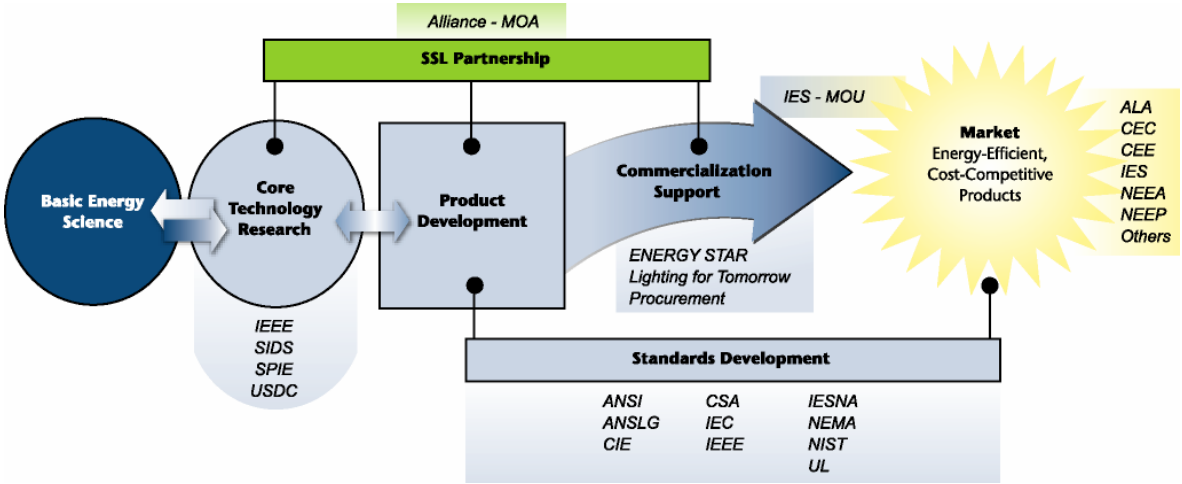


Figure 3-1: DOE Lab to Market Strategy and Partners

Brodrick presented a graph of efficacy (lm/W) versus year to demonstrate the accelerated path to high-efficacy white light solid-state devices that DOE is expected to follow. "We are tasked with a challenge from Congress to follow these two lines," Brodrick said, indicating two plots of data on the graph. The first, labeled "White Light SSL Laboratory" requires the production of experimental laboratory SSL devices with efficacies of 180 lm/W by 2015. The second, labeled "White Light SSL Commercial" sets a goal of 160 lm/W for commercially available white LEDs by the same year. "We've met every R&D goal for the past four years," Brodrick stated, "and we will continue to do it." He emphasized that DOE has 55 R&D projects and $80 million in motion to make sure of that.

To support market introduction of high efficiency SSL products, DOE has developed a five-year SSL Commercialization Support Plan for general illumination SSL luminaires. The draft plan outlines three key objectives:

- To *affect the types of products* adopted by the market
- To *accelerate commercial adoption* of products
- To support applications that *maximize energy savings*

Brodrick emphasized that the plan is a draft that will be updated based on input from workshop participants, DOE partners, and other interested stakeholders. The combined feedback from the Pasadena and Boston workshop participants will guide DOE planning and updates to the draft plan. Current goals of the plan include:

- **Products Brought to Market**:
  Warm White Products
    - 68 lm/W luminaire efficacy
    - 85 CRI (or similar for revised metric)
    - 3500 CCT or less

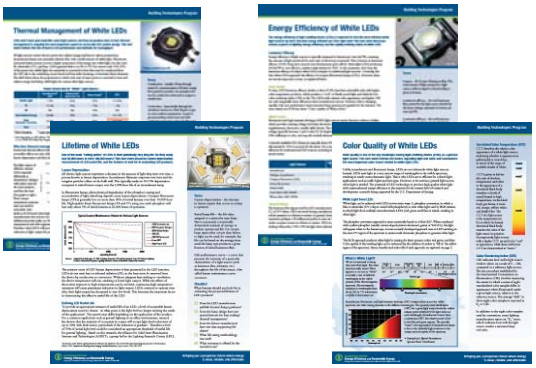
  Cool White Products
    - 88 lm/W luminaire efficacy
    - 70 CRI (or similar for revised metric)
    - 6500 CCT or less
- **Market Adoption**: 1 million units/year (ENERGY STAR)
- **Energy Savings**: 230 GWh per year

DOE's SSL Commercialization Support Plan is designed to address the primary market barriers to market adoption of SSL, including high costs, lack of industry standards and test procedures, and lack of information. Brodrick outlined the key elements of the DOE plan:

- **Buyer Guidance**. This element focuses on developing ENERGY STAR criteria for SSL products, and developing design guidance for lighting designers. "ENERGY STAR is a way to point out that *this* product is good," Brodrick said. "You don't have to do the homework yourself." DOE will also work with IESNA to develop a designer's guide to SSL.
- **Design Competitions**. This element includes the ongoing Lighting for Tomorrow Design Competition, focused on residential lighting, and new competitions for commercial fixture design and architectural lighting design.
- **Technology Demonstrations and Procurements**. DOE technology demonstrations will showcase high-performance SSL products in appropriate applications. Through these demonstrations, DOE hopes to help manufacturers realize significant purchases of demonstration products, and provide end-users with clear data on product performance.
- **Commercial Product Testing Program**. DOE's SSL testing program provides unbiased information on the performance of commercially-available SSL products.

- **Technical Information**. This element includes the development of technology fact sheets on LED basics, lifetime, color quality, thermal management, and other key topics; nine fact sheets are now available. It also includes the activities of the DOE SSL Technical Information Network.
- **Standards and Test Procedures Support**. This element focuses on providing DOE leadership and support to accelerate the standards development process. New standards are expected to be finalized by the end of 2007.
- **Coordination and Leadership**. This element focuses on providing Federal government leadership on SSL, facilitating and coordinating local and regional efforts.

DOE SSL technology fact sheets offer guidance on key issues such as energy efficiency, lifetime, color quality, and thermal management. The LED Application Series includes fact sheets on downlights, under-cabinet, and portable desk lamps, with more to come. See: http://www.netl.doe.gov/ssl/publications/publications-factsheets.htm



3.2 2007 Lighting for Tomorrow Design Competition

Kelly Gordon, Pacific Northwest National Laboratory

Kelly Gordon of PNNL provided a closer look at the Lighting for Tomorrow Design Competition, sponsored by the American Lighting Association, the Consortium for Energy Efficiency, and DOE. The competition began in 2003 with the goals of (1) encouraging and recognizing attractive, energy-efficient residential lighting fixtures; (2) building demand for energy-efficient lighting by demonstrating that it can be attractive and functional; and (3) encouraging technical innovation in energy-efficient lighting. The first three years of the competition focused on fluorescent lighting; the 2006 competition was the first to include a category for LED products.

The winning fixtures from the 2006 competition, shown on the following page, were displayed at the Boston Workshop.

Diode 28 by American Fluorescent
5 watt under-cabinet device

Linear by Lucere Lighting
18 watt under-cabinet device

Halley by Lucesco
19 watt, dimmable, portable desk/floor task light

Lakeland by Progress Lighting
3.5 watt, family of outdoor fixtures

Honorable mentions were given to:

- LED Bullet by American Lighting LLC (in-cabinet luminaire)
- HF2Eye by Osram Sylvania (in-cabinet luminaire)
- Javelin by Albeo (moveable, individually controlled, replaceable LED modules)
- Luxrail by io Lighting (an under-handrail stair luminaire)

Gordon then detailed some issues identified in this first LED competition, including "pixelated" shadowing in linear under-cabinet fixtures, off-state power consumption, color consistency, and unrealistic performance claims.

The 2007 competition again features two categories: CFL fixture families and LED-based fixtures. The LED-based fixture category focuses on niche applications such as under-cabinet, portable desk/task, and outdoor porch/path/step, and recessed downlights (new this year), plus a new Cutting Edge Design category.

Judging criteria include lighting quality, application efficiency, thermal management, and aesthetic appearance. Bonus points are awarded in 2007 for innovative designs that take advantage of unique LED attributes and those that have no off-state power consumption.

Forty-three LED entries were received in May 2007; judging took place in June. Follow-up testing on the finalists was ongoing at the time of the Boston workshop, and winners will be announced in September 2007.

After the presentation, one participant asked if the competition judges had any comments on CFLs versus LEDs. Gordon replied that they were more focused on comparing LEDs to LEDs, and they noted that the quality of LEDs increased pretty significantly since last year. Another attendee, referring to competition requirements for a minimum of 85% driver efficiency, asked for verification that this value applied only to the driver, and not to the whole system. When Gordon confirmed this interpretation, the questioner remarked that he recommended that 85% efficiency should be applied to the entire SSL system to raise the bar.

A third participant asked if all the previous winners of the SSL Lighting for Tomorrow competition were available commercially; Gordon said that they are. Finally, when asked about any issues identified by the judges in the 2007 judging phase, Gordon said that the pixelation problem had decreased, and that off-state power consumption was still evident in some entries. The most consistent complaint from the judges, she said, was low light output from the LEDs.

For more information on this annual competition, visit: www.lightingfortomorrow.com.

3.3 DOE Technology Demonstrations

Bruce Kinzey, Pacific Northwest National Laboratory

Bruce Kinzey from PNNL provided an update on the DOE Technology Demonstrations, designed to showcase commercial LED products for general illumination in a variety of real world applications, to clearly demonstrate the state-of-the-art in terms of both performance and cost effectiveness. The demonstration program's goal is to facilitate rapid market penetration of state-of-the-art SSL products. It is hoped that large scale purchases or promotions of successful products will follow the demonstrations.

For each demonstration, the Department forms a teaming agreement among manufacturers, host site organizations, utilities and energy efficiency organizations, and PNNL.

- Manufacturers donate products to be tested and participate in design activities as desired.
- Host site organizations provide the demonstration site and participate in demonstration-related activities.
- Utilities/energy-efficiency organizations provide contacts with host site organizations and participate in post-demonstration promotion of successfully demonstrated products.
- PNNL identifies products suitable for demonstration, assists in identifying and evaluating suitable host sites, conducts product performance and life testing, evaluates results, and supports subsequent project information dissemination.

DOE issued the first "Invitation to Participate" in March 2007, and received 11 proposals from manufacturers. For Round 1 demonstrations, DOE is proceeding with multiple products from three manufacturers, including display case, under-cabinet, outdoor walkway and street, and security SSL products. In addition, two utility/regional efficiency organizations are involved to date: Pacific Gas & Electric (PG&E) and Northwest Energy Efficiency Alliance (NEEA).

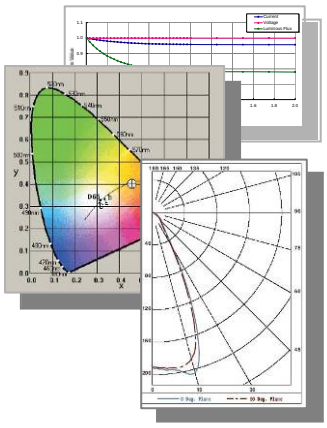
Sixty-one proposals were received for host sites. For Round 1 demonstrations, DOE selected four Federal sites, one California municipality, and two Pacific Northwest residential builders. Others remain in the queue for later rounds of demonstrations. The four Federal sites are the Smithsonian Institution, Port Huaneme Naval Air Station in California, the U.S. Postal Service Facility in Washington, D.C., and the Federal Aviation Administration Test Center in Atlantic City, New Jersey. Kinzey said that the installations will be initiated in August 2007, and the first demonstration will be completed in February 2008.

To stay informed about future "Invitations to Participate" in DOE SSL technology demonstrations, register for SSL UPDATES at the DOE SSL website: http://www.netl.doe.gov/ssl/index.html.

3.4 DOE SSL Commercial Product Testing Program

Jeff McCullough, Pacific Northwest National Laboratory

Jeff McCullough of PNNL offered a more detailed look at the DOE SSL Commercial Product Testing Program. The testing program is designed to provide unbiased performance information on commercially available SSL products. The test results guide DOE planning for ENERGY STAR and demonstration/technology procurement activities, provide objective product performance information to the public, and inform the development and refinement of standards and test procedures for SSL products.



DOE tests SSL products for light output, efficacy, thermal characteristics, lumen depreciation, spectral power distribution, CCT, and CRI.

DOE supports testing of a wide, representative array of SSL products available for general illumination, using test procedures currently under development by standards organizations. Guidelines for selecting products for testing ensure that the overall set of tests provides insight on a range of lighting applications and product categories, a range of performance characteristics, a mix of manufacturers, a variety of LED devices, and variations in geometric configurations that may affect testing and performance. DOE tests for:

- Luminaire light output, efficacy
- Power, thermal characteristics
- Beam and intensity
- Lumen depreciation
- Spectral power distribution, CCT, CRI
- Benchmarking (other light sources)

The Department allows its test results to be distributed in the public interest for noncommercial, educational purposes only. Detailed test reports are available for request on the DOE SSL website at: http://www.netl.doe.gov/ssl/comm_testing.htm. To request a report, users must provide their name and affiliation, and agree to abide by the DOE "No Commercial Use Policy" posted on this web page.

McCullough then detailed the current status of testing program activities. Round 1 and Round 2 testing have already been completed. Round 3 testing is under way, and product selection is commencing for Round 4. Twenty-five products were tested in Rounds 1 and 2, and 15 are being tested in Round 3. A sample comparison of downlight testing results is shown below.

DOWNLIGHTS					
	Manufacturer Published Output or Efficacy	**Output (lumens)**	**Efficacy (lm/W)**	**Correlated Color Temperature (K)**	**Color Rendering Index**
R30 Replacement Lamps					
CPTP 07-08, Warm White	*400 lm*	239.1	27.1	2945	71.8
CPTP 07-09, Cool White	*500 lm*	310.3	34.1	5973	81.9
CPTP 07-13, Warm White, RGB	*400 lm*	405.6	25.9	2689	14.45
CPTP 07-14, Cool White, RGB	*400 lm*	351.6	25.4	4006	13.3
Downlights (complete luminaires)					
CPTP 06-01, Downlight	*40 lm/W (LED)*	193	12.8	3012	70.0
CPTP 06-03, Downlight	*45 lm/W (LED)*	298	19.4	2724	67.3
CPTP 07-04, Downlight	*477 lm*	356.7	11.6	5964	76.4
CPTP 07-05, Downlight	*642 lm*	662.2	25.3	4402	76.0
A-lamp Replacement Lamps					
CPTP 07-06, A19	*27 lm*	10.3	15.7	3161	70.4
CPTP 07-12, A-lamp (~A17)	*"Electricity consumption reduced 80-90%"*	19.7	13.4	25263	79.1

Test results from Rounds 1 and 2 show a wide range of performance in SSL luminaires, and reveal misleading claims in some product literature supplied by manufacturers. DOE test program results help to increase industry awareness, and to validate and refine current testing procedures.

McCullough concluded by emphasizing that Rounds 1 and 2 products tested and designed in 2005-2006, show some LED luminaires rivaling some CFL luminaires in output and efficacy. These findings offer great promise for the next generation of commercially available SSL luminaires.

In the question and answer session, one participant asked where the commercial products were purchased. McCullough replied that they were bought through retailers. Another person asked if off-state power consumption absolutely prohibits a product from receiving ENERGY STAR approval, to which McCullough replied that the current ENERGY STAR standards do not absolutely prohibit all off-state power consumption. A third attendee asked if DOE has seen manufacturers alter performance claims as a result of DOE product testing. McCullough said he is aware of at least one case where confusion concerning "lamp efficacy" versus "luminaire efficacy" was clarified based on feedback from the DOE test program.

The DOE testing program will continue to provide ongoing results and analysis, to increase market awareness about commercially available SSL products, and to support testing standards validation and refinement. Learn more at: http://www.netl.doe.gov/ssl/comm_testing.htm.

3.5 ENERGY STAR for SSL

Jeff McCullough, Pacific Northwest National Laboratory

Jeff McCullough presented an update on the ENERGY STAR criteria for SSL. ENERGY STAR is a voluntary energy-efficiency labeling program that helps consumers identify products that save energy, relative to standard technology. It is designed to set industry-wide specifications for SSL products and to ensure the quality of all products bearing its mark.

In December 2006, DOE released draft criteria for public review and comment. Following a stakeholder meeting in February 2007, DOE issued a second draft in April 2007. McCullough said DOE anticipates the final criteria will be issued in the near term. The effective date will be early 2008, contingent upon the finalization of related standards and test procedures.

The ENERGY STAR criteria for SSL specify a transitional two-category approach. Category A covers near-term niche applications; Category B covers future applications, with future efficacy targets determined as SSL technology improves. At some point in the next three to five years, Category A will be dropped, and Category B will become the sole basis for ENERGY STAR criteria. This transitional approach recognizes the rapidly evolving pace of SSL technology developments, yet allows early participation of a limited range of SSL products for directional lighting applications in Category A.

The DOE ENERGY STAR criteria for SSL focus on **luminaire efficacy** as the key metric, based on the new ANSI/IESNA LM-79 test procedure in development. Luminaire efficacy is defined as luminaire light output divided by ballast/driver input power. McCullough also detailed the overall requirements for CCT, color spatial uniformity, color maintenance, CRI, off-state power, warranty, and thermal management.

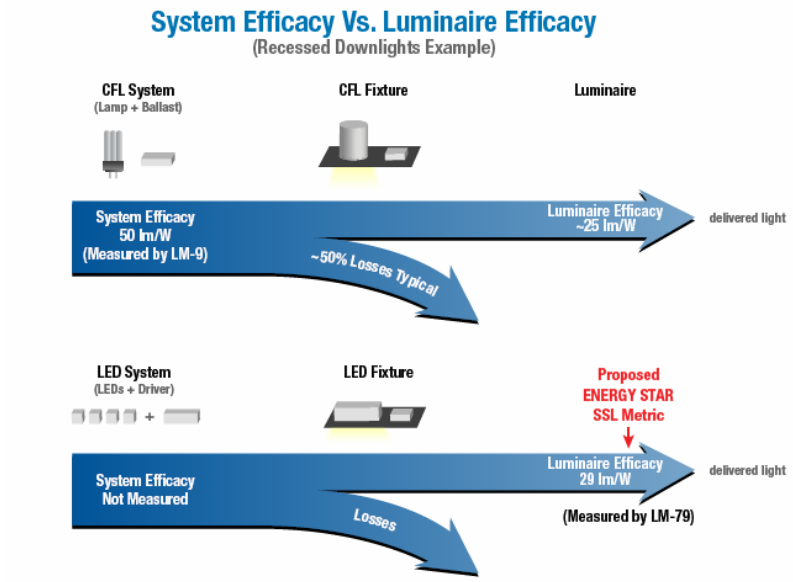


Figure 3-2: Comparison of System Efficacy vs. Luminaire Efficacy

Following the presentation, one participant asked where the temperature measurement used for thermal management of SSL luminaries was coming from. McCullough replied that they are asking manufacturers to locate a thermocouple on the SSL circuit board to provide this critical temperature measurement.

For more information on DOE ENERGY STAR criteria for SSL, or to view the draft criteria, see: http://www.netl.doe.gov/ssl/energy_star.html.

3.6 LED Standards and Test Methods Development

Eric Richman, Pacific Northwest National Laboratory

Eric Richman from PNNL provided an update on the LED standards and test methods development process. In March 2006, DOE hosted a workshop to convene all the key standards-setting organizations, including the Illuminating Engineering Society of North America (IESNA), National Institute of Standards and Technology (NIST), National Electrical Manufacturers Association (NEMA), American National Standards Institute (ANSI), Underwriters Laboratories (UL), International Electrotechnical Commission (IEC), International Commission on Illumination (CIE), and Canadian Standards Association (CSA).

Together the group reviewed LED standards and test development needs, assessed the development process and impacting time lines, and chose the ENERGY STAR time line as their development goal. DOE facilitates ongoing collaboration among these organizations and offers technical assistance in the development of new standards.

Combined ANSI/IESNA meetings and working group conference calls have resulted in substantial progress on SSL/LED performance standards and test methods in development. The following list details current status.

- IESNA RP-16 Nomenclature/Definitions for Illuminating Engineers: Tentatively accepted by IESNA for inclusion as an addendum.
- IESNA LM-80 Lifetime: Currently in final edits; expected to go out for ANSI ballot in July; expected publication by December.
- IESNA LM-79 Electrical and Photometric Measurements: Currently in final edits; expected to go out for ANSI ballot in July; expected publication by December.
- ANSI C78.377A Specification for Chromaticity of White SSL Products: Final edits complete; going out for final ANSI approval in July; expected publication by December.
- ANSI C82.XXX LED Drivers: Currently in draft review by working group.
- UL “Outline of Investigation” for LED Products: In progress.

4. Breakout Sessions: SSL Product Case Studies

A core activity of the two-day workshop involved breakout sessions where participants explored case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees participated in one of five case study breakout sessions. This exercise provided a vehicle for determining whether DOE commercialization plan elements adequately support the market introduction needs of new SSL products. It also served to identify major stakeholders and elements of the plan where their participation might be most valuable, and provided helpful feedback to improve the design of DOE market-based programs.

In breakout sessions, workshop participants explored case studies based on hypothetical SSL products. The groups identified key issues, market barriers, and critical information needs.

Each breakout group was asked to consider one case study, and worked together to:

- Outline a general strategy to sell their target product and identify issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

Brief summaries of the breakout sessions are given here. Complete details of all five case studies are available in Appendix E. In most cases, the hypothetical products in the case studies could not be produced today. The performance assumptions outlined in the case studies are based on what DOE might envision in a few years. For the purposes of this exercise, participants were asked to "suspend reality as to the current viability of the subject product" and focus on identifying critical issues, barriers, and needs.

4.1 Integrated SSL Table Lamp

4.1.1 Scenario

The hypothetical product for Case Study #1 was an integrated SSL table lamp for the residential market. The fixture draws 15 watts and runs at 50 lumens per watt. The estimated retail price is around $40, compared to about $25 for competitive products. The total market for residential portable table lamps is around 40 million units per year. The assumed addressable market is 10-15 million per year.

4.1.2 Market Strategy

This working group decided to name the product "Smart Lamp." What makes the Smart Lamp smart? The following points were identified as market "hooks" to use in promoting the product:

- More efficient; saves energy
- No lamp replacements
- High tech
- Sleek design
- Appeals to savvy consumer
- Intelligence

The Smart lamp compares favorably to standard incandescent lamps and energy-efficient CFL-based lamps.

Smart Lamp Product Advantages	Standard Incandescent Lamp Issues	CFL-Based Lamp Issues
• Lifetime lamp (~15 years) • Full warranty on whole lamp • Energy savings, compared to incandescents and CFLs • ENERGY STAR rating • Safety, reliability • No IR/heat • No more changing bulbs • Sustainability story • Totally dimmable	• Lack of warranty • Short life • Non-ENERGY STAR • High energy use • Heat/IR	• Difficulty identifying ENERGY STAR products at retail • Fluorescent legacy • Mercury • Shorter life than LED • Not dimmable

Target markets for the Smart Lamp will include educated consumers (mid to high end) who are energy/environmentally aware, technically savvy, and prefer modern/contemporary styles. Initial market introduction efforts will focus on the young/student audience.

How will initial success be defined? The group identified the following goals:

- $100K in year 1; grow to $1M in year 5
- Customer satisfaction/acceptance
- Low return rate (<1%)
- Offer more product variations starting in year 2; add features

Market channels will initially include stores like IKEA (sell on sustainability, compliment furnishings); Brookstone (technology sell); Costco; and web sales. Other possible future market channels include:

- Electronics stores (technically savvy customers who read specs)
- QVC (format provides time to explain benefits and unique features)
- Hotels
- Colleges/universities

The group also identified some potential **competitive barriers** that must be addressed through marketing:

- Replaceability/throw-away/waste
- Slightly higher cost
- Limited style variations
- Long life (locks consumer in for 15 years)
- New, unfamiliar technology
- Prior consumer experience with energy-efficient technologies

4.1.3 DOE Plan Elements that Support this Strategy

Element	Comment/Recommendation
ENERGY STAR	Very important
Design guides	Nice to have
Lighting for Tomorrow	Great for publicity
Showcase	Next generation product
Market demonstrations	Good
Testing	Useful with sales channels
Standards	Generic need for industry
Energy efficiency programs	Very important

4.2 Commercial Office OLED Ceiling Light

4.2.1 Scenario

This breakout group was charged with developing market information and support needs for a hypothetical overhead OLED fixture for general office applications. The hypothetical product is expected to be approximately 25% more efficient that current office fluorescent technology, with a 15-year life.

Market Strategy

The group began by making a detailed comparison of the strength and weaknesses of OLED technology versus fluorescent technology. The following fluorescent weaknesses were identified:

- Maintenance – Cleaning, lamp replacement, ballast replacement, and associated labor are a known cost for fluorescent technology.
- Dimming typically requires a more expensive ballast and does not cover a complete 0-100% range.
- Lamp start-up is not completely instant and some warm-up is still common.
- Fluorescent technology contains mercury, a known hazardous waste, which creates potential breakage and disposal issues.
- Fluorescent luminaires take up space in ceiling plenums that might be used for other purposes or eliminated for architectural advantages.
- Design flexibility is limited with a typical box format or linear structure with ballast component and end connections.
- Color has always been an issue (limited choices).

The following OLED strengths were identified:

- Potentially low maintenance cost (approaching zero over 15-year life) compared to fluorescent lamp and ballast replacement needs.
- Minimal cleaning – Fluorescent luminaires typically have multiple light production and reflection surfaces to clean. The typical LED has chip/module surface only.
- Completely dimmable with no added cost – Can be integrated with all types of controls, allowing for maximum energy savings potential.
- Instant on – Very applicable in cold climates compared to typical fluorescent.
- No potential switching-life penalties compared to fluorescent.
- No worksite release of mercury from breakage or mercury disposal issues – Initial information indicates very minimal environmental impact from materials.
- Glare? This may not be an advantage; depends on the intensity of the strip material.
- No damage from vibration compared to fluorescent; better for rough service and high abuse/security applications.
- Low space requirements compared to typical fluorescent luminaire "boxes." This provides more design options such as surface mounting, which can reduce installation and building ceiling construction costs. Reduced plenum intrusion could also lower building costs.
- Potentially better aesthetics with cleaner ceiling "look."
- Significant kWh savings from 1) higher efficiency, 2) better controls application including peak shaving, 3) cooling of waste heat savings.
- Lower wattage needs translate to lower circuit capacity needs for lower electrical system cost.
- Significant maintenance, disposal, cleaning savings over fluorescent technology.
- Design flexibility – The OLED product can be placed more integrally into architecture. Also offers effectively infinite ballast factor adjustment for easier light level/luminaire spacing design.
- DC power can provide advantages in some applications (data centers).

The group called their product "OLuminate," with the slogan "Go Organic and Liberate Your Light!" Their **marketing strategy** was based on the fact that OLED technology has many similarities to standard LED technology and should therefore "draft" on the LED marketing as much as possible. When OLEDs emerge, it is essential to tie in with existing LED success by noting that an OLED is another version or type of LED product with different design and operational characteristics. Their strategy included:

- Focusing initially on new construction.
- Exploring niche applications (schools, prisons, hospitals, warehouses).
- Offering complete design packages.
- Highlighting the product at trade shows and through professional organizations and trade magazines.
- Using "specification sales" (e.g., go to architects, engineers).
- Offering training and demonstrations to highlight applications.
- Stressing OLED pluses over standard LED:
    - Design flexibility (thinner, bendable, diffuse).
    - Less thermal issues because of distributed heat load.

Market barriers for the OLuminate product include:

- First cost.
- Degradation of light output and color over life – Since OLEDs do not fail like other lighting technologies, there is a real risk that they will remain long after their useful life and cause consumer dissatisfaction!
- Distribution systems – Lack of a replacement lamp market will require changes in the distribution system. Distributors need to stock the product for consumers to want to buy, and consumers need to buy for distributors to want to stock.
- Design application guidance – Without guidance, many initial installations may fail and cause dissatisfaction. Education on product and application/installation is critical.
- Newness of technology – Users want to know if the product will meet their needs. Need specifications and standards in place for consumer confidence. Need a rock solid warranty.
- Retrofit vs. new construction – This product will likely only be useful in new construction in the beginning, due to design issues.
- Need case studies and analysis of the radically new product.
- Potential OLED weaknesses:
    - Total luminaire replacement vs. component replacement may cause issues related to consistency of replacement.
    - Lumen depreciation vs. burn-out may cause issues if OLED technology is not replaced when it ceases to provide adequate light (poor performance issues).

4.2.3 DOE Plan Elements that Support this Strategy

Element	Comment/Recommendation
ENERGY STAR	Yes, may not need to be separate from LED
Design/purchase guidance	Yes, highlight important application differences
Lighting for Tomorrow (residential fixtures)	N/A - commercial product
Commercial fixtures competition	Yes, not necessarily different from LED
Lighting design competition	Yes, as part of overall SSL design
Showcase	Yes
Demonstrations	Yes, preference for field performance
Commercial testing	Yes
Technical information	Yes, with focus on appropriate application
Standards/test procedures	Yes, could start right now!
Facilitating local/regional efforts	Yes, focus on state energy groups
Federal leadership	Focus on environmental tie-ins
Other:	Cradle to Grave environmental assessment OLED (LED,SSL) - LEED connection

4.3 Recessed-Can Light Fixture for Residential Use

4.3.1 Scenario

This group was tasked with developing a marketing strategy and assisting activities for a hypothetical LED residential-use recessed can fixture, including the lamp and driver electronics. The LED light source, while specifically designed for the fixture, is configured as a replaceable module to enhance serviceability over the life of the installation. This product is intended to compete with the incumbent energy-saving alternative, a pin-based compact fluorescent built-in residential light fixture with a 17 W source (nominally 1000 lumens). Additional features of the recessed can fixture include:

- 50 lm/W delivered
- 16,000 hours
- Replaceable module to enhance serviceability and future improved design
- $75 price point
- Fully dimmable

4.3.2 Marketing Strategy

The group called their product the *i*Can. The following **product benefits** were identified by the group, some in addition to those described in the case study:

- ENERGY STAR qualified – End users and market channel members will demand this qualification. Promoting the product without this qualification would be premature.
- Fully dimmable – This is a key selling feature, especially since CFL products do not do this well.

- No mercury – A big draw given the trend toward green and energy efficiency products and concern over CFL disposal issues. CFLs contain mercury so this is a big selling feature for the LED *i*Can.
- Long life (fewer replacements) – *i*Can will last longer than CFL products, which is a key selling point.
- Low maintenance – This is related to long life; customers need to change the lighting less often.
- Low power consumption – Energy efficiency is a key selling point.
- No ramp up (instant on) – A key benefit compared to CFL cans. Many customers want "instant on."
- Latest/greatest technology (e.g., iPhone) – Early adopters, our target market, are people who do not shy away from new technology and they like to have the latest/greatest products.
- Reduction in waste heat – LED products run cooler than CFL products so this offers improved comfort, especially for those in hot climates.
- More durable – Less product breakage during installation and fewer callbacks to builders is a desirable feature.
- Aesthetically appealing – The can will enhance the look of the room since it is recessed and has an attractive look.
- Higher CRI, quality of light – An important feature, especially since customers who are considering a CFL may be much happier with the LED product's light quality.
- Easier to install (shallow fixture) and retrofit – Installation is similar to an incandescent fixture and may not require as much room in the ceiling.
- No TV/IR Interference – A drawback to CFL fixtures is that they can cause interference with electronics. This is not an issue with the *i*Can.
- Wet location tolerant – Can be used in bathrooms and other locations where moisture may be an issue (not clear from the case whether this is true, so it is an assumption).
- Eco-Advantages (green) – The eco-friendly trend is one that this product supports, so green builders and other channel members who want to position themselves as providers of green products should consider the *i*Can.
- No fluorescent negative connotation – CFLs suffer from a negative association with fluorescent lighting. LEDs do not have that "baggage."
- Smaller/narrow fixture option – Builders and designers may have more flexibility in lighting design since *i*Can will offer a smaller/narrow fixture option.
- Upgradable modules in future – Buyers may be reluctant to purchase *i*Can given that LED technology is improving so rapidly. Their concerns may be reduced to some degree by knowing that when they need to replace modules, there will likely be improved modules that are compatible with their current system. Also, as technology improves, they can improve their *i*Can s if desired.
- Higher luminaire efficiency – High energy efficiency reduces operating costs and is consistent with a green lifestyle.
- No UV damage to objects/surface (i.e., artwork) – *i*Can can be used in locations where artwork needs to be well lit, but protected from UV degradation.

A subset of product benefits were identified as having significant importance to the various market channel members and end users that *i*Can would need to target. The chart below lists *i*Can product features of interest by target sector.

Feature	End User	Builder	Retailer/ Distributor	Designer/ Specifier
ENERGY STAR	X	X	X	X
Fully dimmable	X	X	X	X
No mercury!	X		X	X
Quality of light	X			X
Energy efficiency/env. friendly	X	X	X	X
Lower utility bill/cost of ownership	X			
Less ladder time	X			
Less cooling	X			X
Lower recall rate – lamp breakage		X		
Equivalent installation		X		
Smaller punch list		X		
Cache/sales appeal		X		
New technology (latest/greatest)			X	

The working group also identified **key partners and allies** to support market introduction and sales of *i*Can. Allies include:

- Energy Efficiency Program Sponsors (EEPS)
- ENERGY STAR
- Industry – NEMA, ALA, electrical distributors and supply houses, builders/developers, building suppliers, big box retailers (DIY), realtors
- Design community – American Institute of Architects (AIA), International Association of Lighting Designers (IALD), IES
- National Association of Home Builders (NAHB), state building associations
- Code officials – Underwriters Laboratory (UL), National Fire Protection Program (NFPA), Internal Code Council (ICC/IECC), Canadian Institute of Energy (CIE)
- Green builder advocates - Green Building Association (USGBC), Builders for Social Responsibility, Habitat for Humanity
- Academic institutions - trade schools, university programs, Lights for Learning, CEU training

The general approach to marketing *i*Can will utilize Regional Pilot Programs. The target market for *i*Can, at least initially, will be the new residential construction and remodeling market. The strategy for reaching this market will involve the following:

- Identify pilot regions/areas where EEPs are active and interested, where construction is high, and where codes require high efficiency lighting (e.g., California and Washington).
- Coordinate with EEPs and other allies (see above).
- Provide training/education to builders, electrical contractors, code officials, retailers.
- Attend trade shows including Lightfair, NAHB, EEBA, International Builders Show (IBS), Dallas Market, Build Boston (AIA). Attend residential regional shows in pilot areas.

- Offer demonstrations in model homes.
- Develop media program (Google, national and local TV, Internet, wire services).
- Offer warranties to help overcome buyer concern over high replacement cost.

4.3.3 DOE Plan Elements that Support this Strategy

The group identified ways they would like to see DOE and others support *i*Can. Their recommendations included:

- Incentive programs – EEPS and others could provide incentives (buydowns, etc.) as part of their programs. DOE could assist by supporting tax incentives or providing information.
- Public service announcements – DOE should work with EEPS and others to develop PSAs to create awareness for this new lighting technology. Local and national TV could be encouraged to run the PSAs as part of a campaign to be "green."
- Merchandising materials – DOE could coordinate with EEPS, utilities, ENERGY STAR, and others to provide "foundational" materials that EEPS could use in their regions. For example, inserts for local home and garden magazines could be developed. Also, designs for in-store displays that show LED vs. incandescent energy use might be developed. Once the design is developed, EEPS and others could order the displays.
- Training materials for educating lighting design professionals and students, builders, electrical contractors, code officials, realtors, and others should be developed. DOE could help by developing core curriculum. Retailers are important because they should recognize the added value that LED downlights bring to a home and be able to explain this to potential buyers.
- DOE should continue its testing and demonstration programs.
- DOE should complete an ENERGY STAR specification for LEDs.
- DOE should continue to support the development of stringent residential energy codes.
- DOE should support high profile demonstrations for SSL residential downlights in real applications. This could involve coordination with other government programs/agencies such as HUD (PATH).
- DOE should continue to support design competitions and awards such as Lighting for Tomorrow.
- DOE should support bulk procurements of this product category. An approach such as that used in http://www.quantityquote.com/ might be taken.

4.4 Outdoor Walkway and Streetscape Lighting System

4.4.1 Scenario

This group's product is a hypothetical LED outdoor walkway and streetscape light with a 10'-16' mounting height and a replaceable light engine (LED and driver) module. Outside area lighting is a difficult challenge for SSL. High Pressure Sodium (HPS) lights are quite energy efficient, have reasonably long lifetimes, and deliver a lot of light. LEDs nonetheless offer two potential advantages in this application.

- First, LED source technology today is capable of an efficiency approaching those of HPS and soon will likely surpass it. The directionality of the LEDs should also allow luminaire efficiency to be higher than for HPS.
- Second, the LED color quality is much better than HPS. In some applications, such as historic districts and pedestrian/shopping areas, better color may be a selling point.

The LED product price is somewhat higher than a comparable HPS fixture. The energy savings are considered important in this application, and should appeal to municipalities and utilities.

4.4.2 Marketing Strategy

The group named their product StreetSMART, and adopted the slogan "Making intelligent choices and taking them to the street!" The group began by identifying a number of **barriers to market penetration**:

- A typical LED beam is too narrowly focused and requires additional optics to meet the distribution pattern requirements of outdoor lighting codes.
- The application of lumens to the target surface is not a well understood concept; people are instead going to compare luminaires based on total output and thus may undervalue LED products.
- LEDs must be made to conform to current lighting standards, which do not necessarily fit them well.
- Future standards are going to have to be modified to recognize unique LED properties to maximize their potential impact.
- Because this is a new technology with new characteristics, training is needed for inspectors and permitting officials, installers, design professionals, and staff involved in the procurement and specification process for lighting equipment.
- Color uniformity among LED chips even in the same batch may not be tightly enough controlled for some applications.
- Available power at the pole varies greatly across different locations; requires a fair amount of product flexibility to be viable in different markets.
- What is in it for the end user? The value proposition is not yet well enough understood.
- Differing goals for capital and operating budgets make a tougher case for higher priced technologies, even if they operate more efficiently.
- Stakeholder buy-in will lag until this is a consistently proven, established technology.
- Buy-in must be achieved across the entire supply chain as any resistance along the way causes unwanted delays.

- Climate limitations of the product (e.g., operation in hot climates) complicates its selection and use.
- A new replacement schedule will be required compared to the established technology; now the light sources will outlast the drivers (and any change requiring re-education results in additional market resistance).
- Inconsistent and inadequate information available on LED products causes additional resistance. People are more reluctant to purchase products they do not understand.
- Glare issues must be overcome.
- Architectural design conflicts (e.g., a product that performs well may still encounter resistance from designers who consider it "ugly").
- Rapid obsolescence causes decision makers to be reluctant to jump in. Today's technology will be cheaper tomorrow and out of date by the day after that.
- Lack of standardization and lack of a second source for replacement parts introduces additional concerns for product specifiers.
- Some municipal and state bidding practices require multiple products, i.e., tying your fortunes to a single manufacturer is problematic and risky.
- The variety of system characteristics (e.g., who owns the lamps and who provides the power at any given location, rate schedules, etc.) introduces a fair amount of complexity to designing a marketing plan for outdoor lighting.

The group then identified the following information needs:

- Think globally regarding education. The need for education extends to everyone involved in the decision chain. Different players may require different emphases.
- Illuminance comparisons between alternative light sources – How much light actually gets applied to the desired surface for this technology vs. that one?
- Accurate life-cycle cost comparisons need to be available to enable more informed decisions.
- The total retrofit cost needs to be available rather than just the equipment cost.
- Who are the stakeholders and decision makers in a given situation?
- Product availability – Purchasers are going to want to know that they will be able to get replacement parts in the future.
- Local code requirements can vary greatly; these must be known before a particular installation can proceed.
- Any unique requirements of the space must be known to enable an adequate design to be drawn up for that space.
- What is the voltage of the distribution network for this installation? 660V, 480V, 220V, 120V?
- Educational seminars are needed to bring decision makers up to speed on the technology, allowing them to make more informed decisions. These need to be unbiased, product neutral seminars to the greatest extent possible.
- Notification of upcoming projects (solicitations, etc.) around the country are useful for identifying potential installation opportunities.
- What is the planning budget cycle? Usually lighting system purchases in a given location are only budgeted once every several years, as a new system and some

amount of replacement parts are ordered at one time. Generally, those are used up before another purchase is pursued at that location.

The group also identified **critical allies** to support market introduction of StreetSMART.

- City/municipal managers and staff (everyone who may be involved in selection of a system for outdoor lighting).
- Third party installers – You need to know and be in touch with the folks that will be installing your system.
- Civic environmental organizations – May have significant inroads into a large number of communities.
- ENERGY STAR/HUD/DOE/GSA.
- Successful adopters – Installation case studies and previously experienced points of contact greatly help in convincing new prospects of the value proposition.
- Media.
- Insurers – Questions or concerns on the part of insurers can prevent a project from advancing.
- IRS – The tax code can be structured to greatly assist implementation, e.g., tax credits for efficiency investment.
- Industry associations help in spreading the word and making contacts.
- ESCO, other promoters, and EE program delivery folks can be critical liaisons between manufacturers and host sites.
- Parts and component suppliers must be matched and aligned with your business plans; if the components are not available, neither is your product.
- Developers/architects/designers must know and agree with the benefits of your product for it to be incorporated into their work.
- DDA, DDC, BIDS – Downtown Development Associations, etc., frequently work with municipal authorities such as the mayor's office and can help get advanced technologies implemented as a part of efforts to rejuvenate city centers, etc.
- Local/regional economic development agencies can similarly be proponents of advanced technologies and can provide inroads to certain customers.
- Certifying labs can certainly prevent implementation if they do not understand or support the technology.
- State policymaking community.

Major points in the group's **marketing strategy** include:

- Identify markets, end-users for the product.
- Prioritize markets, then focus attention on a few of the primary markets to get started.
    - Identify appropriate strategy for each market, which may involve emphasizing different perspectives, e.g., an environmental message, a color quality message, etc.
    - Needs analysis – What are the needs of the various markets that your product can meet?
- Assess the competition, both from other LED vendors and from other lighting products.

- SWOT Analysis – Know the advantages and benefits of your product to be able to counter customer concerns over the additional first cost. But also be straightforward about the product's limitations.
- Develop and provide a customer education plan, so they know what questions to ask lighting vendors, and they are familiar with the current best practices in the industry, etc.
- Help the customer establish the specifications needed for their application (e.g., is white light or high color rendition important, etc.).
- Look at means of reducing risk to the end user (e.g., is an extended warranty possible for your product and would it provide competitive advantage in the market?).
- ROI analysis will be important in putting together the business case for the LED product.
- ENERGY STAR rating should be a goal, and publicized, if attained.
- Case studies should be assembled in preparation for demonstrating past performance to potential buyers.
- Identify incentives and other financing available to help improve economics to end users.
- Identify incentives from the manufacturer that would increase attractiveness to potential users, e.g., training and purchase options ("if you buy right now – or buy more than X units – we'll give you an extra 10% off").
- Ownership options, e.g., lease vs. purchase – this may reduce perceived risk to end-users by giving them the opportunity to purchase "light" rather than "lighting equipment." Also allows for easier upgrade as the technology evolves, and removes this responsibility from the end-user.
- Identify partners for maximizing your market impact.
- Clearly identify the value proposition for your product.

4.4.3 DOE Plan Elements that Support this Strategy

The following list details suggestions from the group—areas where DOE efforts are perceived to be most helpful in pursuing the market strategy outlined above.

- Focus on "capacity building" – Giving people the increased capacity to make informed decisions about their lighting alternatives. Example activities include:
    - Public service announcements, e.g., communications to provide early notification of important upcoming events such as "ENERGY STAR is coming for LED products."
    - Information targeted specifically towards decision makers as opposed to a more general audience.
    - Appearance at trade shows to spread information among those not normally tracking developments in lighting technology.
    - Development of materials intended to distinguish LED from CFL for the public; currently the public may associate ENERGY STAR lighting with CFL technology due to the recent media push, and it is important that they recognize the difference in the technologies.
- Help establish buyer consortiums – Enabling smaller players to build market power through collaboration.

- Develop activities specifically designed to help the smaller companies in the LED innovation and manufacturing community. This is where much of the current innovation in the industry is coming from.
- Establish an LED catchphrase/branding logo for product identification, e.g., "Intel Inside" or the logos for CD and DVD. This should be displayed on every product incorporating LEDs.
- Establish an application-based design competition (e.g., publish the characteristics of a given kitchen space and hold a competition to design the most energy-efficient, attractive and cost-effective lighting system composed entirely of LEDs).
- Produce a "Consumer Report" for LED products that reflects more quality in the product evaluation than does the current ENERGY STAR rating. Achieving ENERGY STAR status does not mean that a product is well built, only that it uses less energy relative to other products in its class.
- DOE could do more to publicize the high performing products and to expose the inferior products tested in its Commercial Product Testing Program.

4.5 LED Spotlight for Retail Store Lighting

4.5.1 Scenario

This group was charged with marketing a hypothetical adjustable LED spotlight intended for accent lighting in retail applications. A typical competing conventional product would be a 50W halogen MR16. The LED has a substantial advantage in terms of energy efficiency – a factor of two – and it lasts over ten times as long as the halogen. The cost of the product is higher than the conventional technology, but the energy savings will make up the first cost difference in only a year or so.

The group produced this summary of product attributes:

- Slightly higher light output, 1000 lm vs. ~750 lm for an 50 W MR-16
- 50% energy savings
- 40 lm/W vs. 16-18 lm/W
- Little or no IR/UV
- Aimed "hot"
- Durable/robust (benefits for frequent display configuration)

4.5.2 Marketing Strategy

The group named their product the EcoSPOT LED Spotlight, and developed a detailed comparison of their product and its competition. MR-16 strengths and weaknesses are detailed below.

MR-16 Halogen Strengths	MR-16 Halogen Weaknesses
• Good color – 2800-3200K • Beam control – Very tight beam spreads and a wide variety of options • Directional – Put light where it is needed • Sparkle – Point light sources with good color quality add "sparkle" to retail environments • Inexpensive first cost – $3-$5 • Compact form factor – Small lamps with relatively high total flux • Market acceptance/low risk – Lamps are ubiquitous, well established and popular • Dimmable • Readily available – Can be purchased everywhere	• Relatively short life – 2-3000 hours • Maintenance Costs ($$$) – Frequent replacement due to short life increases labor costs • Waste – Frequent replacement due to short life increases the waste stream • High IR (heat) – Safety, liability, melting chocolate • Weak base – There have been problems with the high operating temperature leading to damage of the fixture socket • Magnetic transformer – Over time magnetic transformers (needed to convert 120 VAC to 12 VDC) have a tendency to hum/buzz, causing audible background noise • Inefficient • Fragile – The lamps are sensitive to non-passive failure (NPF); oil on fingers can etch the glass and cause a stress fracture

EcoSPOT strengths and weaknesses are detailed below.

EcoSPOT Strengths	EcoSPOT Weaknesses
• Very long life – 10+ times the life of an MR-16 • Significantly reduced maintenance • Efficient • Short ROI • Safety (no NPF) • Dimmable (w/color shift) – There tends to be a color shift when LED systems are dimmed • Hot aiming – This is seen as a major advantage as halogen lamps are quite hot and are especially vulnerable to failure (filaments are brittle at high temperatures) • Solid-state power supply – No audible noise • No UV/IR • Robust/rugged – "Takes a licking and keeps on ticking"	• Relatively high cost • Color stability – The current state of technology is such that there is significant variation with devices of the same color; this can be controlled by specifying the appropriate bins • New form factor – No industry standard interface • Bigger thermal management (fixture) – The required heat sinking may be a detractor • Not great for wall-washing – Possibility for color variation for side-by-side products • Limited awareness – It is a new technology that will require a significant information infrastructure • Availability – Products are not yet available and with new market introduction it is unlikely that distribution would be uniform • High risk – No one wants to be the first one on the block to invest in new technology • Forward compatibility – Lack of standard interfaces make future replacement a problem

The **marketing plan** developed for EcoSPOT includes holding focus groups with retailers, to better understand their key needs/motivation. Demonstration projects would follow a phased process: Benchmarking demonstrations, demonstrations of market

readiness, and demonstrations to test field performance. Volume purchases would help to bring the cost down and establish target specifications for manufacturers to reach.

The group also envisioned EcoSPOT Leased Lighting: partnerships with utilities and ESCOs for performance-based, shared savings installations. This strategy would basically use the ESCO approach to guarantee performance and offer turn-key solutions. And finally, the group identified the need for climate change/green marketing, combined with audience-oriented messaging.

Hot buttons for various decision makers in the retail environment were identified:

Lighting designer "hot buttons"	**Retailer "hot buttons"**	**Sales representative "hot buttons"**
• The "green card" • The "cool factor" (state-of-the-art) • Flexible color tuning • Architectural effects	• In-house designer, consultant, facility manager • Needs to be simple (similar to incumbent) • Energy efficient • No radiated heat • "Green" • Sales are paramount!!! • Reduced life cycle costs (energy savings, maintenance)	• Need education • Uniform information • Demo kits • Brochures • Web site • Tech support • Comparisons • Better labeling

The group identified a number of **market barriers** to address**:**

- First cost.
- Inconsistent information – Wild claims of performance are likely to cause confusion and delay in market acceptance.
- Risks – Concerns over the potential for poor product performance.
- Designer reluctance – Do you want to be the first person to specify LEDs for a large client???
- Forward compatibility.
- New electrical infrastructure.
- Installation/O&M.
- Color stability.
- Lack of reliable system integrators – Not many people fully understand the nuances of the technology.
- Independent system testing – Need for third party testing of products to demonstrate performance.
- Fragmented industry.
- Availability.

4.5.3 DOE Plan Elements that Support this Strategy

Element	Comment/Recommendation
ENERGY STAR	Establish ENERGY STAR criteria as this will help define high performing products. In the case of CFLs, manufacturers will not sell product unless it is labeled.
Design guidance/application guides	Desperately needed to provide the lighting industry with design information.
Lighting design competition for interior (retail spaces)	Perhaps IES?
Field demonstrations	Yes!!!
Product testing	Testing is required, but be careful about sharing too much negative information.
Standards and test procedures	A must!

The team also drew up a "wish list" of desired features that would make the EcoSPOT easier to market to retailers:

- Color tuning – 3 preset CCT settings. The idea here would be to have user selectable presets so the desired CCT could be chosen with the same lamp.
- Programming/addressability – The ability to "address" each lamp individually.
- Open source color tuning (not proprietary!).
- Flexible optics – The ability to add a variety of secondary optics for maximum flexibility.
- Water/corrosion resistance – Seen as an issue with current technology that would expand the applications for the product, once resolved.

5. Tour of Osram Sylvania's LIGHTPOINT® Institute for Lighting Technology

The first day of the Workshop ended with a tour of Osram Sylvania's LIGHTPOINT® Institute for Lighting Technology in Danvers, Massachusetts. The LIGHTPOINT facility features interactive demonstration units and training aids for live, classroom-based education for architects, lighting designers, specifiers, distributors, utility representatives, and others.

Robert Cilic, Manager of Technical Education, welcomed workshop attendees to the facility. Cilic was joined by Sameer Sodhi, General Manager for LED Systems, and Sergio Mazon, Training Specialist, as they offered an overview of Osram's worldwide business operations and SSL efforts, and guided attendees through LIGHTPOINT's hands-on, see-it-yourself experience.

For example, three light panels with controls allow users to vary color temperature to compare yellow, blue, and red shades of white light. This process helps users associate lighting colors with correlated color temperature (CCT) values. Three identical department store window displays enable users to compare different lighting sources (incandescent, fluorescent, LED, sodium vapor) and see the effects on the eye's perception of color. Similarly, participants could vary the color temperature of the LEDs in the displays to see for themselves how varying CCTs affect color perception.

Nearby, a wall of products displays the latest lighting innovations; another wall of products enables participants to examine technical aspects of lamps and ballasts to better understand light output, energy, and power quality. The LIGHTPOINT facility is used for a range of training sessions, including "Lighting Design and Applications" and "LED Lighting Applications."

Following the tour, a reception hosted by Osram Sylvania provided attendees with an opportunity for further discussion and networking.

Sameer Sodhi from Osram Sylvania describes panels with LED solutions for white and color signage, as well as the ColorMix LED system.

6. Market Perspective on SSL

Vrinda Bhandarkar, Strategies Unlimited

Vrinda Bhandarkar of Strategies Unlimited presented an analysis of "Emerging SSL Markets for General Illumination." She began by emphasizing that the market is worldwide in scope: the main production and consumption occur in the U.S., Europe, Japan, Taiwan, South Korea, China, and Southeast Asia. Her analysis looks at the market in terms of packaged devices, focusing on high brightness LEDs.

The high-brightness LED market is segmented by applications that have similar functionality, according to Bhandarkar. The segments include:

- Mobile appliances (cell phones, laptop computers, PDAs)
- Signs and displays (video screens, stadium scoreboards)
- Automotive (brake lights, back-up lights, dashboard lights)
- Signals (stop/walk signals)
- Illumination

"Illumination is only 5% of the global market," Bhandarkar noted, "but it is the fastest growing segment." The market for high-brightness LEDS for lighting was $205 million in 2006. This number is projected to reach $1 billion by 2011, with white light LEDs dominating the market with a 60% share in 2011.

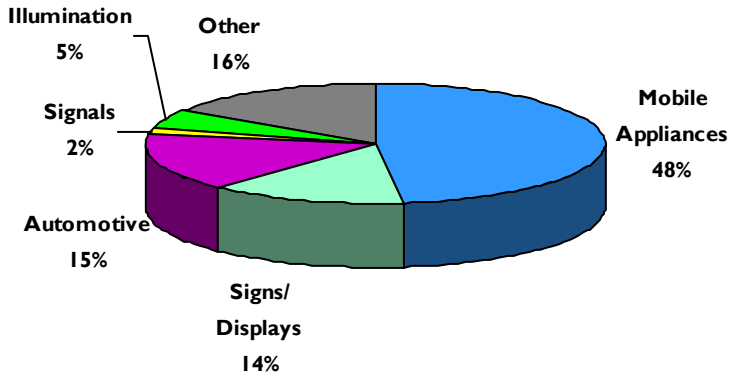


Figure 6-1: 2006 Market by Application

Currently, most white LEDs are used as backlighting for cell phones. The fastest growing portion of the illumination segment is architectural lighting, although most applications use colored lights. General illumination white light applications are starting to emerge as a significant application.

According to Bhandarkar, the market drivers for SSL include:

- Visual appeal (saturated colors)
- Long lifetime
- Compact form factor

- Lack of radiated heat
- Low-voltage operation
- Energy efficiency

She referred to WalMart's adoption of LED refrigerated display case lighting as "the SSL story of the year," noting that other supermarket chains are likely to follow WalMart's lead. Bhandarkar summarized the opportunities for SSL, noting that SSL offers unique lighting solutions, delivers value (on a cost-of-ownership basis), and can be adapted to unique physical environments.

A number of challenges remain, including high initial costs, competition from alternatives for energy efficiency, and the need for high efficiency light engine/fixture design. Bhandarkar highlighted comparisons of incandescent, CFL, and LED technology, noting trends in early DOE testing program results and the cost of lighting (present and future).

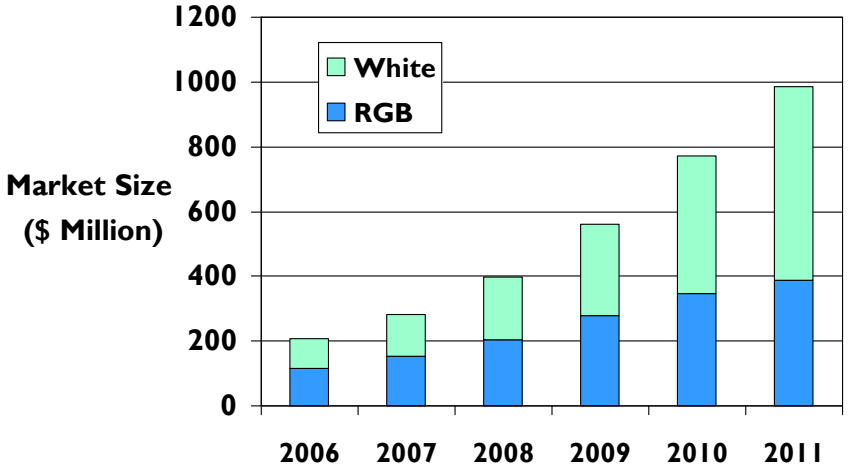


Figure 6-2: Forecast for LEDs in Lighting Market

Bhandarkar concluded her presentation with a recap of the LED lighting market outlook:

- Niche lighting applications will continue to grow.
- General illumination (white light applications) will become increasingly important.
- Outlook presumes continuing improvement in white LED and luminaire price/performance.
- Outlook presumes substantial marketing efforts to penetrate the conventional lighting market.
- Overall forecast is $1 billion by 2011.

In the question and answer session, someone asked if the cost of ownership numbers presented were just for energy; Bhandarkar replied that they were the costs of the initial purchase plus energy. Another participant asked if they used the same criteria for market analysis in Europe as they do in the United States. "There's more landscaping in Europe," Bhandarkar replied. "They're looking for stylistic effects rather than efficiency."

7. New York State Research and Development Authority Activities in SSL

Priscilla Richards, Marsha Walton, Mark Michalski, NYSERDA

Priscilla Richards, Project Manager of NYSERDA Energy Efficiency Services, kicked off a multi-speaker presentation by introducing NYSERDA's mission to "Use innovation and technology to solve some of New York's most difficult energy and environmental problems in ways that improve the State's economy." "What a great fit SSL is for this mission," Richards said.

Pictured, left to right: Mark Michalski, Marsha Walton, Priscilla Richards, and James Brodrick.

She next introduced Marsha Walton, Project Manager for Lighting Research and Development at NYSERDA, who described several current SSL projects funded by NYSERDA. These projects focus on new product development, demonstration, testing and evaluation, and education. For example, RPC Photonics and RPI Lighting Research Center are collaborating to improve the efficiency, visibility, and performance of LED signage. Another project by LED Specialists involves development of a PAR 20 size LED lamp driver for an LED spot lighting system.

Applied NanoWorks is working to develop nanophosphors that increase the efficacy and white color of LEDs. The same company is also collaborating with RPI Lighting Research Center to develop phosphors for high efficiency green LEDs.

A field demonstration of LED lighting in freezer cases is under way, to provide retailers with data on energy usage, costs, shopper surveys, and sales. The Lighting Research Center supports education activities related to application and testing of SSL products. In addition, Walton mentioned the Lighting Research Center's LED Lighting Institute, which offers a hands-on workshop for professionals interested in learning more about LED technologies and applications.

Next, Mark Michalski, Project Manager for Residential Efficiency and Affordability Programs, talked about NYSERDA's plans for promoting SSL in the residential sector. Right now, says Michalski, the market is ready to accept LEDs in niche applications such as holiday lighting, nightlights, flashlights, and solar-powered LED lights. Michalski

talked about NYSERDA efforts to promote LED holiday lighting, including the decoration of Schenectady City Hall with more than 500 LED lights, decoration of an ENERGY STAR model home with 1,500 LEDs, and holiday lighting contests.

Priscilla Richards concluded with a recap of NYSERDA's commercial/industrial efforts, emphasizing the National Lighting Product Information Program (NLPIP) which publishes the "Lighting Answers" newsletter to educate the public about energy efficient LED lighting solutions. NYSERDA is also promoting programs for LEDs in new construction, existing buildings, and peak energy load management projects.

After the presentation, one audience member said that they purchased LED nightlights for giveaways, but were not satisfied with the light output. Another attendee said that he experienced the same problem with holiday lights. Richards offered to supply both with a list of recommended manufacturers for these products.

8. Next Steps

Moving forward, the Department of Energy will continue to work closely with the SSL industry, energy efficiency organizations, utilities, and standards-setting organizations to guide market introduction of high-performance SSL products.

In August, DOE began installation for the first round of SSL technology demonstrations, designed to showcase market-ready LED products for general illumination in a variety of real world applications. The first round includes installation of Osram Sylvania HF-2 sticks in display cases at the Smithsonian Institution, and Ruud Beta Lighting roadway lights on a municipal road in the city of Oakland. DOE plans to initiate Round 2, with a request for new products from manufacturers, in late 2007. See http://www.netl.doe.gov/ssl/techdemos.htm for more information.

In mid-September, the 2007 Lighting for Tomorrow design competition winners will be announced at the American Lighting Association Conference in San Antonio, Texas. Information on the winning fixtures will be posted at: http://www.lightingfortomorrow.com/.

In the fall of 2007, DOE will continue to work closely with NEEP and the Consortium for Energy Efficiency (CEE) to establish the DOE Technical Information Network for SSL (TINSSL). The network is designed to increase awareness of SSL technology, performance, and appropriate applications. As with all SSL project performers, NEEP and CEE were competitively selected to support DOE in this effort. To learn more, see http://www.netl.doe.gov/ssl/technetwork.htm.

DOE anticipates that final ENERGY STAR criteria for SSL products will be issued in the near term. The effective date is expected to be early 2008, contingent on related standards and test procedure finalization. For more information, or to view the second draft criteria, see http://www.netl.doe.gov/ssl/energy_star.html.

Combined ANSI/IESNA working groups anticipate the release of the following new standards and test procedures by the end of 2007:

- IESNA RP-16 (Definitions)
- IESNA LM-80 (Lifetime)
- IESNA LM-79 (Electrical and Photometric Measurements)
- ANSI C78-377A (Chromaticity)
- ANSI C82-XX1 (Power Supply)
- UL 8750 (LED Safety).

To learn more, see http://www.netl.doe.gov/ssl/standards_dev.html.

Rounds 1 and 2 of the DOE SSL Commercial Product Testing Program have been completed. Detailed test results on all 25 products from both rounds (downlights, replacement "bulbs," outdoor wall, desk/task, and refrigerated display case products) are available by request at: http://www.netl.doe.gov/ssl/comm_testing.htm. Round 3 testing

of 15 products (plus technology demonstration products) is under way, and product selection is commencing for Round 4.

In FY2008, DOE anticipates the start of several new programs and expansion of existing programs. The draft Five-Year SSL Commercialization Support Plan will be updated with input from the Pasadena and Boston workshops. DOE will host the annual SSL R&D Workshop on January 30-February 2, 2008, followed by the Market Introduction Workshop in July.

To stay apprised of DOE SSL program activities, progress, and events, register for ongoing updates at: http://www.netl.doe.gov/ssl/index.html.

9. Appendices

APPENDIX A: Workshop Attendees
APPENDIX B: DOE SSL Program Fact Sheets
APPENDIX C: DOE Commercialization Support Plan Draft
APPENDIX D: Case Studies 1-5
APPENDIX E: Index of Acronyms

APPENDIX A: Workshop Attendees

DOE SSL Workshop: Boston MA
July 16-17, 2007

Attendee List

Andy Albrecht
GE Consumer & Industrial

Gabe Arnold
Efficiency Vermont

Ben Avery
Steelcase Inc.

Josh Baribeau
Canaccord Adams

Ira Baskin
L. C. Doane

Doug Baston
North Atlantic Energy Advisors

Thomas Betty
Nebula Lighting Systems

Vrinda Bhandarkar
Strategies Unlimited

Lisa Bodin
Applied Proactive Technologies

Jim Brodrick
U.S. Department of Energy

Charles Bruzzone
3M Optical Systems Division

John Burns
Cape Light Compact

Michael Caliendo
Lockheed Martin

Gerald Carey
NSTAR

Michael Cavallo
The Clinton Foundation

Jasjeet Singh Chaddah
Grameen Surya Bijlee

Michael Chan
Avago Technologies

John Chandler
Maine Environmental Protection

Susan Coakley
Northeast Energy Efficiency Partnerships

Sarah Cornelius
Akoya

Tom Coughlin
National Grid

Pete Couture
International Light Technologies

Peping Dee
Litecontrol

Peter Di Maso
Texas Instruments

Dhaval Doshi
Cabot Corporation

Kevin Dowling
Color Kinetics

Eileen Eaton
Consortium for Energy Efficiency

Alexei Erchak
Luminus Devices, Inc.

Franz Euler
Euler Lighting

Steve Fink
Color Kinetics

Rebecca Foster
Consortium for Energy Efficiency

Peter Franck
Lightolier

Kelly Gordon
Pacific Northwest National Laboratory

Derek Greenauer
D&R International

Frank Gundal
NSTAR

Robert Harrison
OSRAM SYLVANIA

Angela Hohl-AbiChedid
OSRAM SYLVANIA

Peter Jacobson
Con Edison

Ron Johnston
Western Massachusetts Electric Company

Carol Jones
Pacific Northwest National Laboratory

Robert Karlicek
Luminus Devices, Inc.

Mark Kelly
GE Lumination

Garo Khanarian
Rohm and Haas

Mustansir Kheraluwala
OSRAM SYLVANIA - Electronic Control Systems

Bruce Kinzey
Pacific Northwest National Laboratory

John Kiru
Toronto Association of Business Improvement Areas

Catul Kiti
D&R International

Robert Koenig
The Clinton Foundation

Ira Krepchin
E Source

Kama Krishna
Grameen Surya Bijlee

Veronica Kulman
Tacoma Public Utilities

Rene LaPlante
Massachusetts Senator Rosenberg

Bruce Ledgerwood
LEAN

Jon Linn
Northeast Energy Efficiency Partnerships

Rochelle Lockridge
3M

Melissa Lucas
Northeast Energy Efficiency Partnerships

Karen Marchese
Akoya

Howard Mastropiero
Independent Electric

Jeff McCullough
Pacific Northwest National Laboratory

Dan Mellinger
Efficiency Vermont

Guival Mercedat
NSTAR Electric

Mark Michalski
NYSERDA

Paul Montesino
Northern Energy Services

Kirsten Murray
Satco Products

Magesh Nandagopal
GE

David Neal
Avnet LightSpeed

Susan Oman
Nexus Market Research, Inc.

Tim O'Sullivan
LED Lighting Fixtures

Brian Owen
FIRSTeam - LEDesignWorks

Tim Palucka
Akoya

Brett Parker
Heatron, Inc.

Paul Pattison
U.S. Department of Energy

Ray Phillips
Articulated Technologies

Dan Polito
Lamina

John Potts
3M Display & Graphics Lab

Priscilla Richards
NYSERDA

Eric Richman
Pacific Northwest National Laboratory

Stephen Ritson
Applied Proactive Technologies

Cody Rose
Applied Proactive Technologies

Michael Russom
Efficiency Vermont

David Ryan
D&R International

Linda Sandahl
Pacific Northwest National Laboratory

Edward Schmidt
Northeast Energy Efficiency Partnerships

Adam Scotch
OSRAM SYLVANIA

Margaret Song
Cape Light Compact

Carl Spector
Boston Air Pollution Control Commission

Tom Spehalski
OSRAM SYLVANIA

Catherine Stanley
Northeast Energy Efficiency Partnerships

Ruth Taylor
Pacific Northwest National Laboratory

Maria Thompson
OSRAM SYLVANIA

Elizabeth Titus
Northeast Energy Efficiency Partnerships

Kimberly Tomlinson
GE

Dean Trigg
National Resource Management, Inc.

Carl Uthe
Lockheed Martin

Heather Vail
Lockheed Martin

Bethany Vasecka
Northeast Energy Efficiency Partnerships

Donald Vigneau
Northeast Energy Efficiency Partnerships

Frederick Wajcs
Northeast Utilities

Marsha Walton
NYSERDA

Fred Welsh
Radcliffe Advisors

Ray Yingling
Eastman Kodak Co.

Yi Zheng
OSRAM SYLVANIA

Maura Zlody
Boston Environment Dept.

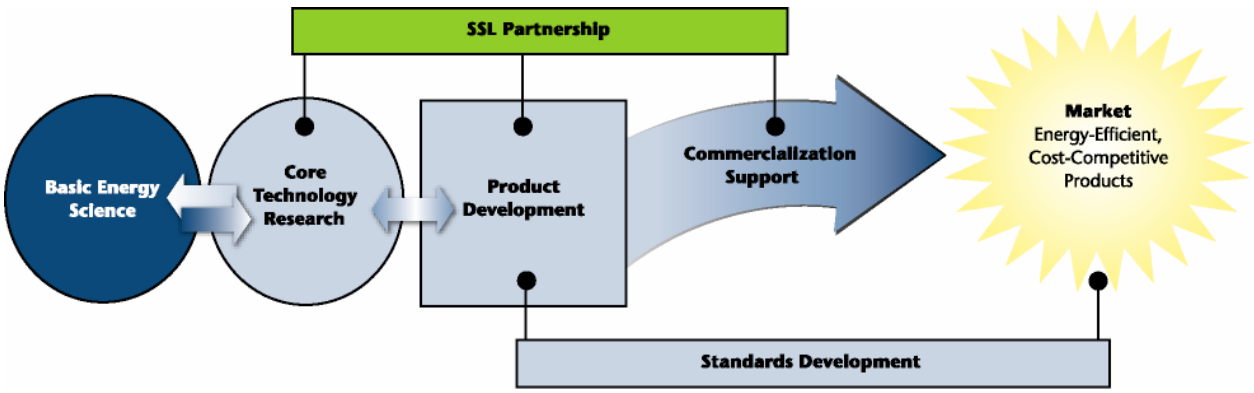
APPENDIX B: DOE SSL Program Fact Sheets

Guiding Technology Advances from Laboratory to Marketplace

The U.S. Department of Energy's solid-state lighting (SSL) portfolio draws on the Department's long-term relationships with the SSL industry and research community to guide SSL technology from laboratory to marketplace. DOE's comprehensive approach includes Basic Energy Science, Core Technology Research, Product Development, Commercialization Support, Standards Development, and an SSL Partnership.

Basic Research Advances Fundamental Understanding. Projects conducted by the Basic Energy Sciences program focus on basic scientific questions that underlie DOE mission needs. These projects target principles of physics, chemistry, and the materials sciences, including knowledge of electronic and optical processes that enable development of new synthesis techniques and novel materials.

DOE SOLID-STATE LIGHTING PORTFOLIO



- DOE's **Basic Energy Sciences** program conducts basic research to advance fundamental understanding of materials behavior. Project results often have multiple applications, including SSL.
- **Core Technology Research** projects focus on applied research for technology development, with particular emphasis on meeting efficiency, performance, and cost targets.
- **Product Development** projects focus on using the knowledge gained from basic or applied research to develop or improve commercially viable materials, devices, or systems.
- To ensure that these investments lead to SSL technology commercialization, DOE has drawn on its ongoing relationships with the SSL industry and research community to develop appropriate **Commercialization Support** strategies.
- In addition, DOE is working with the National Electrical Manufacturers Association (NEMA), the Next Generation Lighting Industry Alliance (NGLIA), and other standards setting organizations to accelerate the **Standards Development** process.
- The **SSL Partnership** provides input to enhance the manufacturing and commercialization focus of DOE's SSL portfolio.

Core Technology Research Fills Knowledge Gaps. Conducted primarily by academia, national laboratories, and research institutions, Core Technology Research involves scientific research efforts to seek more comprehensive knowledge or understanding about a subject. These projects fill technology gaps, provide enabling knowledge or data, and represent a significant advance in our knowledge base. They focus on applied research for technology development, with particular emphasis on meeting technical targets for performance and cost.

Product Development Utilizes Knowledge Gains. Conducted primarily by industry, Product Development is the systematic use of knowledge gained from basic or applied research to develop or improve commercially viable materials, devices, or systems. Technical activities focus on a targeted market application with fully defined price, efficacy, and other performance parameters necessary for the success of the proposed product. Project activities range from product concept modeling through development of test models and field-ready prototypes.

Commercialization Support Activities Facilitate Market Readiness. To ensure that DOE investments in Core Technology Research and Product Development lead to SSL technology commercialization, DOE has also developed a national strategy to guide market introduction of SSL for general illumination. Working with the SSL Partnership and other industry and energy organizations, DOE is implementing a full range of activities, including:

- ENERGY STAR® designation for SSL technologies and products
- Design competitions for lighting fixtures and systems using SSL
- Technical information resources on SSL technology issues, test procedures, and standards
- Testing of commercially available SSL products for general illumination
- Coordination with utility, regional, and national market transformation programs
- Technology procurement programs that encourage manufacturers to bring high-quality, energy-efficient SSL products to the market, and that link these products to volume buyers

SSL Partnership Provides Manufacturing and Commercialization Focus. Supporting the DOE SSL portfolio is the SSL Partnership between DOE and the NGLIA, an alliance of for-profit lighting manufacturers. DOE's Memorandum of Agreement with NGLIA, signed in 2005, details a strategy to enhance the manufacturing and commercialization focus of the DOE portfolio by utilizing the expertise of this organization of SSL manufacturers.

The SSL Partnership provides input to shape Core Technology Research priorities, and accelerates implementation of SSL technologies by:

- Communicating SSL program accomplishments
- Encouraging development of metrics, codes, and standards
- Promoting demonstration of SSL technologies for general lighting applications
- Supporting DOE voluntary market-oriented programs

Standards Development Enables Meaningful Product Comparisons. The development of national standards and rating systems for new products enables consumers to compare products made by different manufacturers, since all companies must test their products and apply the rating in the same way.

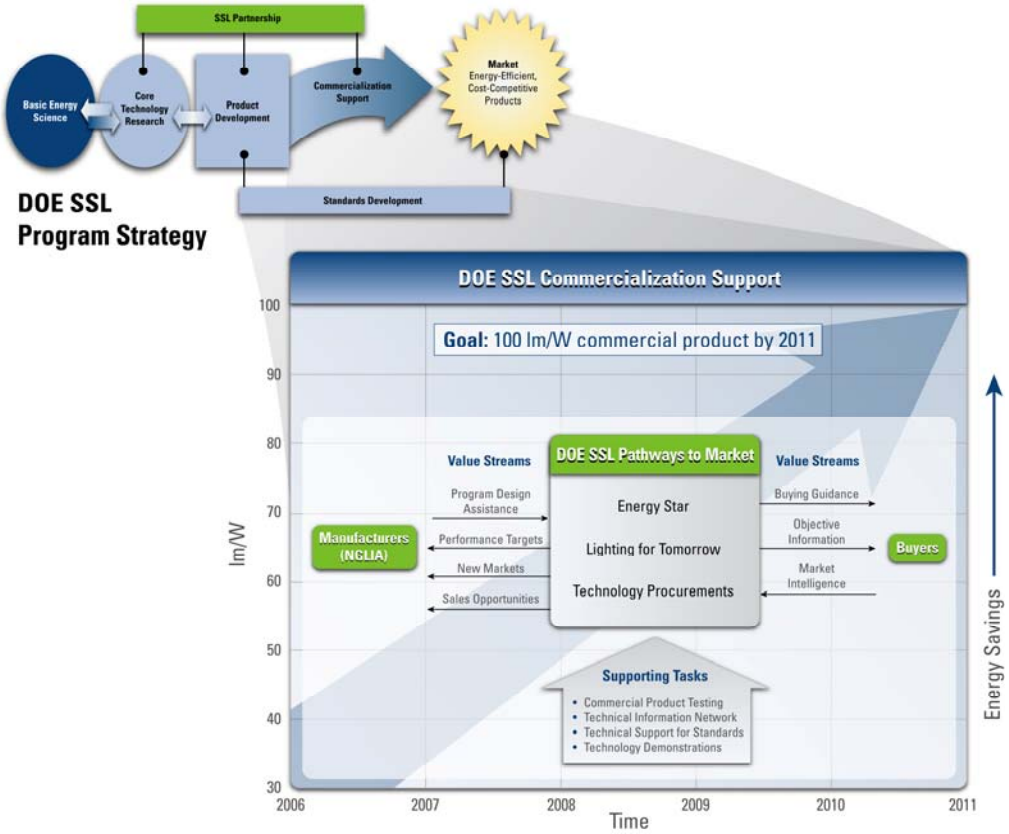
No ratings or standards have yet been set for SSL products, but DOE is working closely with the Illuminating Engineering Society of North America, NEMA, NGLIA, and other standards setting organizations to accelerate development of needed standards and test procedures.

Guiding Market Introduction of High Efficiency, High-Performance SSL Products

The U.S. Department of Energy (DOE) has developed a comprehensive national strategy to guide solid-state lighting (SSL) technology from lab to market. To leverage DOE's $100 million investment in SSL technology research and development (R&D), and to increase the likelihood that this R&D investment pays off in commercial success, DOE has developed a commercialization support plan. The plan focuses DOE resources on strategic areas to move the SSL market toward the highest energy efficiency and the highest lighting quality.

DOE's plan draws on key partnerships with the SSL industry, research community, standards setting organizations, energy efficiency groups, utilities, and others, as well as lessons learned from the past. Commercialization support activities are closely coordinated with research progress to ensure appropriate application of SSL products, and avoid buyer dissatisfaction and delay of market development. The diagram below details the key components of DOE's commercialization support strategy, and how they relate to DOE's goals for luminous efficacy over time.

DOE SSL PATHWAYS TO MARKET



DOE SSL Pathways to Market

DOE supports three key pathways to market: ENERGY STAR®, the Lighting for Tomorrow Design Competition, and Technology Procurement. These pathways, described below, provide manufacturers with performance targets and information on new markets and sales opportunities. They provide buyers with objective information and purchasing guidance. In return, DOE partners including the Next Generation Lighting Industry Alliance (NGLIA) and the Technical Information Network provide feedback to guide DOE planning and program design.

ENERGY STAR for SSL. ENERGY STAR is a voluntary energy efficiency labeling program that helps consumers to identify products that save energy, relative to standard technology. DOE issued draft ENERGY STAR criteria for SSL luminaires in December 2006.

Lighting for Tomorrow Design Competition. In partnership with the American Lighting Association and the Consortium for Energy Efficiency, DOE sponsors Lighting for Tomorrow, a design competition that encourages and recognizes excellence in design of energy-efficient residential light fixtures. In 2006, a solid-state lighting competition was added to the existing program focused on compact fluorescent lighting (CFL) fixtures.

Technology Procurement. Technology procurement is an established process for encouraging market introduction of new products that meet certain performance criteria. DOE has employed this approach successfully with other lighting technologies, including sub-CFLs and reflector CFLs. DOE plans to employ technology procurement to encourage adoption of new SSL systems and products that meet established energy efficiency and performance criteria, and link these products to volume buyers and market influencers.

Additional Activities Support Primary Pathways

- **Commercial Product Testing Program.** DOE's SSL Commercial Product Testing Program provides unbiased information on the performance of commercially-available SSL products. The test results guide DOE planning for ENERGY STAR and technology procurement activities, provide objective product performance information to the public, and inform the development and refinement of standards and test procedures for SSL products.
- **Technical Information Network.** DOE's technical information network facilitates learning and promotes energy efficiency and quality in the deployment of SSL. The network, comprised of energy efficiency program sponsors, utilities, lighting researchers and designers, and others, will meet regularly to share technical information about SSL and to provide feedback from the market (retailers, builders, and consumers) on market needs and barriers.
- **Technical Support for Standards.** LEDs differ significantly from traditional light sources, and new test procedures and industry standards are needed to measure their performance. DOE provides leadership and support to accelerate the standards development process, facilitating ongoing collaboration among standards setting organizations and offering technical assistance in the development of new standards.
- **Technology Demonstrations.** DOE is planning SSL technology demonstrations in both the residential and commercial building sectors to provide real-life experience and data involving SSL installations in various applications. DOE will verify performance of the selected SSL products, including measurement of energy consumption, light output, color consistency, and interface/control issues. Demonstration results will inform DOE technology procurement activities and provide buyers with reliable data on product performance.

5-YEAR SSL COMMERCIALIZATION SUPPORT PLAN

July 2007
DRAFT

U.S. Department of Energy
Solid-State Lighting Program

5-YEAR SSL COMMERCIALIZATION SUPPORT PLAN
July, 2007
DRAFT

Plan Summary

This plan sets out a strategic, five year framework for guiding DOE's commercialization support activities for *high-performance solid-state lighting (SSL) products for the U.S. general illumination market*. The commercialization support activities described in this plan, which span federal fiscal years 2008 to 2012, are intended to affect the types of SSL general illumination products adopted by the market, to accelerate commercial adoption of those products, and to support appropriate application of those products to maximize energy savings.

DOE has established aggressive FY12 goals for these activities, including goals for the types of products brought to market, the market adoption of those products, and the energy savings achieved through use of SSL products. These goals are for the combined effect of DOE's SSL commercialization support and R&D investment, as well as the leveraged activities of its partners. Among the goals are inducing the market introduction of SSL luminaries achieving 68 lumens per Watt (lm/W) luminaire efficacy (for warm white products), and 88 lm/W (for cool white products). Other FY12 goals include sales of 1 million high-performance SSL luminaires per year, and achieving annual energy savings of 230 gigawatt hours (GWh).

The plan identifies seven key SSL market needs for DOE commercialization assistance. They are:

1) Effective product purchasing and architectural design guidance (to guide buyers to products that perform well, and to provide lighting designers with critical new technology application information)
2) State of the art products and lighting designs (to convincingly illustrate the energy saving potential of the technology)
3) Highly visible examples of model SSL general illumination applications (to illustrate the practicality and cost effectiveness of SSL)
4) Independent performance test results on commercially available products (to overcome widespread confusion on actual product performance)
5) Objective, widely available technical information from a credible, respected source (to help fill information gaps and clear up widespread misunderstanding of the technology, its attributes, and its limitations)
6) Industry standards and test procedures for SSL general illumination products (to enable basic market infrastructure)
7) Coordination of local, regional, and federal SSL commercialization activities (to maximize effect of invested public and ratepayer money)

If met, the above market needs can collectively help drive down the costs of SSL by creating near-term market opportunities for SSL, which in turn generates revenue for SSL manufacturers to invest in R&D and lower-cost production. The market needs were used for deciding which types of programs and projects DOE should create, and what general form they should take. Those projects and programs are identified in this plan as the plan's *key strategic elements*. They are:

1) **Buyer Guidance**
   a) ENERGY STAR
   b) Design Guidance
2) **Design Competitions**
   a) Lighting for Tomorrow (Residential Fixtures)
   b) New Commercial Fixture Design Competition
   c) Architectural Lighting Design Competition
3) **Technology Demonstrations/Procurements**
   a) Demonstrations of Market Readiness
   b) Demonstrations to Test Field Performance
4) **Commercial Product Testing Program**
5) **Technical Information**
   a) Technical Information Development and Dissemination
   b) Technical Information Network
6) **Standards and Test Procedures Support**
7) **Coordination/Leadership**
   a) Facilitating and Coordinating Local and Regional Efforts
   b) Federal Government Leadership

The above seven strategy elements represent DOE's comprehensive approach to SSL commercialization support. They depend on active an extensive involvement from program partners, ranging from energy efficiency program sponsors, to industry associations, to standards setting bodies. The resources, expertise, and networks these program partners bring to the efforts represented by this plan greatly multiply any market development DOE can achieve on its own, and thus are a critical element to the success of this plan.

Progress toward achieving plan goals with the above strategic elements will be closely monitored and reported annually. Those annual reports will track new commercial product performance, product sales, and estimated annual energy savings.

Introduction

Purpose

The purpose of this plan is to set out a strategic, five-year framework for guiding DOE's commercialization support activities for *high-performance SSL products for the U.S. general illumination market*. The purpose of the commercialization support activities described in the plan is threefold. DOE plans to create the conditions, specifications, standards, opportunities, and incentives that:

(1) *affect the types of SSL general illumination products adopted by the market*, emphasizing high-performance products likely to reduce energy use and satisfy users;
(2) *accelerate commercial adoption* of these products;
(3) *support appropriate application of these products to maximize energy savings*.

DOE intends the sum of its efforts to shift the commercial adoption curve for high-performance SSL products ahead by five years, yielding large energy and economic savings. DOE estimates that annual energy savings from full implementation of this plan (in combination with its SSL R&D plan) are 230 GWh (site electricity use), or 2.5 terra Btus (primary energy use) by FY12.

DOE Role in SSL Commercialization

The primary responsibility for commercializing advanced SSL technologies rests with the private sector. SSL system and component manufacturers are best positioned to decide how and when products are brought to market. However, DOE has a commercialization role for SSL, derived from explicit authority given DOE in Sec. 912 of EPAct 2005:

> *The Secretary [of Energy] shall carry out a Next Generation Lighting Initiative in accordance with this section to support research, development, demonstration, and commercial application activities related to advanced solid-state lighting technologies based on white light emitting diodes.*

In addition, SSL commercialization activities are consistent with the 2006 DOE Strategic Plan, which states DOE will,

> *Work collaboratively with other Federal agencies, private industry, and other countries to accelerate the adoption of technologies capable of substantially reducing global emissions of greenhouse gases and other emissions.*

DOE is uniquely positioned to carry out these activities. First, DOE has a large and growing SSL R&D program that provides a strong technical basis from which to develop and implement an SSL commercialization support program (DOE 2006b). SSL technology is fundamentally different from conventional lighting technologies. It requires different standards, methods of measurement, product integration, thermal design, optical design, and a range of different approaches for successful lighting application. All this makes a thorough understanding of SSL technology necessary for development and implementation of an appropriate and well-considered commercialization assistance program.

In addition, DOE's extensive experience with a wide range of commercialization methods and programs, especially when coupled with its SSL technical understanding, make DOE the right agency to carry out this program. And last, DOE entered into a memorandum of understanding with the Next Generation Lighting Industry Alliance (NGLIA) on February 2, 2005, which, among other things, stated NGLIA's intent to cooperate with DOE on developing and implement commercialization support activities such as ENERGY STAR.

DOE can offer significant value to SSL commercialization efforts, as evidenced by the Next Generation Lighting Industry Alliance's (NGLIA) decision to enter into an agreement with DOE calling for commercialization cooperation. That value derives from far more than provision of additional financial resources. It also derives from:

- DOE and the federal government are valued by the public as being providers of unbiased, technically sound information. With the buying public holding a healthy skepticism about vendor product claims, SSL manufacturers value the credibility DOE can bring to this new market.
- DOE's can influence federal purchasing. Many federal agencies look to DOE for assistance and advice on which new energy saving products to investigate and buy. Through FEMP, federal regulations, and a wide range of conferences and technical materials, DOE exerts important influence on what SSL products should be considered for purchase by other federal agencies.
- DOE can provide leadership to the industry, and serve as a focal point to catalyze private activity that competing companies may otherwise be reluctant to engage in. For example, SSL manufacturers now widely credit DOE with having successfully organized the industry into developing a wide ranging set of industry standards and test procedures for SSL application to the general illumination market.
- DOE can facilitate partnerships with a wide range of organizations that can influence the rate at which SSL products are accepted by the market. By working with electric utilities, non-profit organizations, state energy offices, trade associations and others, DOE can rally the assistance of organizations motivated to engage in activities that lead to efficiency improvements and energy savings.
- DOE can use the highly valued and widely recognized ENERGY STAR program to leverage a wide range of activities in support of SSL product commercialization.

DOE's role and value in SSL commercialization was also recognized by the Illuminating Engineering Society of North America (IESNA), with which DOE entered into a Memorandum of Agreement on July 17, 2006 to enhance, among other things, DOE's SSL commercialization support efforts. The MOA expresses the organizations' plans to work closely together, including an agreement to:

> *Develop and maintain guides and procedures to assist the lighting community in the photometric measurement of SSL devices and other technologies to support DOE programs (including the development of ENERGY STAR® criteria for solid-state lighting), and to provide consistency and uniformity in photometric reports.*

Time Frame

This plan addresses the period FY08 – FY12.

Goals

The goals of DOE's SSL commercialization support efforts for the five years covered by this plan are directly related to the purposes of these activities, as described in the above Purpose Section. They are to create and catalyze market conditions, specifications, standards, and market opportunities that, influence products brought to market, accelerate market adoption of SSL products, and achieve energy savings through use of SSL products. Specifically, they are:

(1) **Products Brought to Market:** induce the manufacture and purchase of highly efficient LED luminaires, leading to U.S. market introduction by 2012 of *warm white* LED general illumination luminaires achieving at least:
   a. 105 lm/W luminous efficacy[1];
   b. 68 lm/W luminaire efficacy;
   c. 85 CRI (or similar revised color quality metric), and;
   d. at most, 3500 K CCT.

   For *cool white* LED general illumination luminaires, at least:
   a. 135 lm/W luminous efficacy;
   b. 88 lm/W luminaire efficacy;
   c. 70 CRI (or similar revised color quality metric), and;
   d. at most, 6500 K CCT.

(2) **Market Adoption of Products:** accelerate the development of the SSL general illumination market such that high-performance (ENERGY STAR compliant) luminaires achieve sales of 1 million units per year by 2012.

---

[1] To date, there is no ANSI/IESNA published test procedure for measuring luminous efficacy of LED devices or arrays. Until such test procedures ar estandardized, DOE will use manufacturer reported values of "typical luminous flux" which are typically measured with device temperature at 25° C while power is applied to the device in a brief (milliseconds) pulse. For the LED luminous efficacy calculation, wattage of the device is assumed to be the product of typical forward voltage (V_F) and typical drive current (I_F).

(3) **Energy Savings:** influence application of SSL luminaires such that electricity savings of at least 230 GWh per year are achieved by FY12.

Desired End State

DOE can be confident that further market support is unnecessary and can justify conclusion of its SSL commercialization support efforts when the U.S. market for high-performance SSL products achieves a state DOE believes will be self sustaining, as defined by the following characteristics:

(1) **Products Brought to Market:** at least ten 100+ lm/W (luminaire efficacy) *warm white* general illumination luminaires, and at least ten 120+ lm/W *cool white* general illumination luminaires, are offered for sale by major fixture manufacturers (and are available in most major markets through normal lighting equipment sales channels) in each of the following product categories:
Warm White Products: residential recessed downlights, commercial recessed downlights, and commercial office ambient lighting

Cool White Products: pole-mounted roadway luminaires and high-bay luminaires

(2) **Market Adoption of Products:** high-performance luminaires (ENERGY STAR compliant) comprise 10% of annual sales in the above product categories

(3) **Energy Savings:** annual U.S. electricity savings of 5 TWh per year[2]

<u>Market Barriers and Needs Addressed by Plan</u>

Owing to its technical potential for greatly improved performance and greatly reduced costs, the longer-term barriers to market acceptance faced by SSL technology appear modest. Its nearer-term barriers are primarily a consequence of the technology being in its early stages of technical maturation, and its nascent introduction to the market as a general illumination product. As large private and public R&D investments steadily yield large improvements in the technology, SSL is expected by most observers to make its way deeply into the general illumination market. But still at question are how long this market penetration will take, and the extent of resulting energy savings. Accordingly, this plan is focused on near-term market barriers and needs.

The primary near-term market barriers faced by SSL general illumination products are:

- High costs relative to competing technologies

[2] DOE estimates it is technically achievable and economically feasible for SSL to produce U.S. electricity savings of 50 TWh per year by approximately 2015 (DOE 2006).

- Lack of industry standards and test procedures for SSL general illumination products
- Lack of information (for buyers, designers, and lighting fixture manufacturers)

To help overcome these barriers, DOE has identified the following high-priority market needs. If met, they can collectively help drive down the costs of SSL by creating near-term market opportunities for SSL, which in turn generates revenue for SSL manufacturers to invest in R&D and lower-cost production. Market need 6) addresses the lack of standards and test procedures, and the remaining market needs address the lack of information market barrier.

Market Needs:

1) Effective product purchasing and architectural design guidance (to guide buyers to products that perform well, and to provide lighting designers with critical new technology application information)
2) State of the art products and lighting designs (to convincingly illustrate the energy saving potential of the technology)
3) Highly visible examples of model SSL general illumination applications (to illustrate the practicality and cost effectiveness of SSL)
4) Independent performance test results on commercially available products (to overcome widespread confusion on actual product performance)
5) Objective, widely available technical information from a credible, respected source (to help fill information gaps and clear up widespread misunderstanding of the technology, its attributes, and its limitations)
6) Industry standards and test procedures for SSL general illumination products (to enable basic market infrastructure)
7) Coordination of local, regional, and federal SSL commercialization activities (to maximize effect of invested public and ratepayer money)

Each of the above market needs is used to generate strategy elements for SSL commercialization support, which are discussed in the following section.

Key Strategy Elements

The following key elements collectively are the DOE strategy for SSL commercialization support. They were selected on the basis of:

- Consistency with appropriate federal role
- Expected impact on market development
- Expected impact on potential energy savings
- Expected program costs not exceeding available resources

SSL Commercialization Support 5 Year Plan

Goals: By 2012, induce market introduction of general illumination SSL warm white luminaires that achieve 68 lm/W and cool white luminaires that achieve 88 lm/W (luminaire efficacy), facilitate 1 million annual sales of high performance SSL luminaires, and achieve 230 GWh annual energy savings.

Strategy Elements

1) **Buyer Guidance**
   a) ENERGY STAR
   b) Design Guidance
2) **Design Competitions**
   a) Lighting for Tomorrow (Residential Fixtures)
   b) New Commercial Fixture Design Competition
   c) Architectural Lighting Design Competition
3) **Technology Demonstrations/Procurements**
   a) Demonstrations of Market Readiness
   b) Demonstrations to Test Field Performance
4) **Commercial Product Testing Program**
5) **Technical Information**
   a) Technical Information Development and Dissemination
   b) Technical Information Network
6) **Standards and Test Procedures Support**
7) **Coordination/Leadership**
   a) Facilitating and Coordinating Local and Regional Efforts
   b) Federal Government Leadership

1) Buyer Guidance

Market Need: *Effective product purchasing and architectural design guidance (to guide buyers to products that perform well, and to provide lighting designers with critical new technology application information)*

a. ENERGY STAR®

DOE observed a large number of new SSL general illumination products entering the market in recent years. Based on its knowledge of SSL technology and its own product testing, DOE became concerned that a large number of these products would likely disappoint their buyers due to low energy performance, low color quality, short lives, and other problems. DOE feared a repeat of the early market introduction mistakes that plagued the compact fluorescent lamp market for many years − thus greatly delaying their widespread market acceptance. In addition, DOE recognized that rapid

technological progress being made with white, high-power LEDs meant the market could be supplied in the near-term with high performance LEDs capable of providing substantial energy savings, and providing good customer satisfaction. As one of the federal agencies responsible for the ENERGY STAR program, DOE developed ENERGY STAR criteria for SSL general illumination products, with the intent to help steer businesses and consumers to high performance, good quality SSL products. DOE issued the first public draft of its proposed ENERGY STAR SSL criteria in December, 2006, and after modifications in response to public comment, plans to finalize those criteria in late Summer, 2007.

The proposed ENERGY STAR SSL criteria are presently narrow in scope, allowing ENERGY STAR qualification for only a small number of general illumination applications, such as under-cabinet lighting, task lamps, and recessed downlights. In part, this reflects the limited number of general illumination applications currently appropriate for SSL technology, and in part, reflecting DOE's "go slow" approach to applying ENERGY STAR criteria to general illumination − given the entire lighting industry is in the early stages of learning how best to use this technology for the general illumination market. However, due to the technology's rapid rate of improvement, DOE anticipates quick growth in the number of general illumination applications appropriate for SSL. Accordingly, DOE plans to regularly and frequently expand the number of lighting applications covered by the criteria, based on findings of on-going analysis of the technology.

At some point in the future, approximately three years after finalization of the initial ENERGY STAR SSL criteria, SSL technology will have matured to the point that it will no longer be feasible to base the criteria on individual lighting applications. At that point the technology will be robust enough that specific, application by application criteria are no longer necessary. More general criteria, applying to much broader categories of general illumination products will be substituted to make the criteria more easily managed.

DOE also anticipates the lighting industry will learn about a wide range of SSL application issues as experience is gained with SSL in the general illumination market. Some of these issues may need to be addressed through future changes in the ENERGY STAR criteria. For example, early users of commercial ambient lighting systems may find that a large number of products suffer from significant glare problems due to the very high luminous intensity of high-power LEDs. Such a problem many need to be addressed through glare mitigation requirements in ENERGY STAR criteria. Consistent with its planned go-slow approach, DOE will add to and expand the scope of its criteria as DOE and the lighting industry become more familiar with the particular challenges of using SSL for general illumination.

As described in Section 5 below (Technical Information), DOE plans to develop and disseminate a wide range of information addressing SSL technology and its appropriate application to general illumination. This informational effort will be closely coordinated

with ENERGY STAR, providing timely and useful information to ENERGY STAR partners involved in selling or promoting ENERGY STAR SSL products.

b. Design/Purchasing Guidance

Most lighting designers are unfamiliar with SSL technology. Its unique characteristics, flexibility, and appropriate application will take time for lighting design professionals to learn. From DOE's perspective, a very important element of this learning process will be how to apply this technology in a manner that meets lighting quality needs yet maximizes potential energy savings.

As the technology evolves, the range of applications to which it can be appropriately applied will grow, though use of conventional lighting technologies will continue to be more efficient for a number of lighting applications for some time. Helping lighting designers and their customers sort through this complicated terrain will increase the likelihood that the U.S. can attain the early energy savings potential of the new technology.

An attractive starting point for DOE efforts to provide purchasing and design guidance is the Federal sector, where DOE has a lead role in providing technical support to federal agency efforts to reduce energy consumption. A new Executive Order announced January 24, 2007 directs federal facilities to reduce energy use by 30 percent by end of FY2015, relative to 2003 levels.[3] SSL will potentially play an important role in reaching this goal. Initial outreach by DOE to federal agencies has elicited a high level of interest in demonstrating and evaluating SSL technologies. Early federal sector experience in terms of specific product performance, energy savings in specific applications, product costs and procurement issues, and impact on maintenance and lighting service will be captured, synthesized into guidance documents, and shared with the federal sector through the Federal Energy Management Program, the Inter-Agency Energy Task Force, and the Federal Utility Partnership Working Group.

The guidance documents will be organized by application, for example, task lighting for modular offices, recessed downlighting, or parking area lighting. To be useful to those responsible for selecting lighting technologies for federal facilities (i.e., facility managers, consulting lighting designers, lighting contractors, etc.), the following information is necessary: 1) product performance data based on traceable test procedures and in standard IES photometric file format; 2) cost information, including purchase, installation and service costs; 3) information on in-situ performance, such as results of field testing.

As DOE builds a database of performance information on a variety of luminaire types (through the Commercial Product Testing Program), and implements demonstrations in various federal and non-federal facilities, DOE will produce a series of LED design and purchasing guidance documents. This information will be of use and interest not only in

---

[3] http://www.whitehouse.gov/news/releases/2007/01/print/20070124-2.html

the federal sector, but also in the wider lighting design community. Professional lighting designers look to IESNA Design Guides and Recommended Practice documents as key references. Information developed for the federal sector will be fed into the IESNA committee process for incorporation into these types of references.

DOE's Building Technology program will work closely with the IESNA and the Federal Energy Management Program to develop appropriate design and purchasing guidance for the federal and private sectors.

2) Design Competitions

Market Need: *State of the art products and lighting designs (to convincingly illustrate the energy saving potential of the technology)*

a. Lighting for Tomorrow (Residential Fixtures)

DOE co-developed a residential lighting fixture design competition in 2002 in cooperation with the Consortium for Energy Efficiency and the American Lighting Association. In its fourth year of operation (2006), Lighting for Tomorrow (LFT) added for the first time a category requesting proposals for high-performance, residential SSL luminaires. The competition attracts a substantial amount of attention in the lighting industry, primarily through the lighting trade press. Judging by the volume and quality of press covering the LFT in recent years, the program has very successfully raised the profile and awareness of attractive, well-designed energy-efficient residential lighting fixtures.

DOE plans to continue to cooperate in LFT with its partners, focusing its resources on the SSL component of the competition. Planned strategic changes for DOE's role in LFT include:

- expanding the scope and profile of the SSL component of LFT as more high-performance SSL luminaires are introduced into the market;
- highlighting luminaire efficacy and potential energy savings, and;
- emphasizing leading edge technology by getting NGLIA manufacturers more involved in the program, and cooperating in joint proposals with fixture manufacturers.

b. Commercial Fixture Design Competition (Commercial Fixtures)

In addition to LFT, which is a residential fixtures-only program, DOE plans to explore the development of a similar commercial fixtures-only program, perhaps in collaboration with the Illuminating Engineering Society of North America (IESNA). (A commercial fixtures program needs to be separate from LFT because the American Lighting Association's primary focus is the residential lighting industry.) Its operation and purpose would be very similar to LFT, but oriented toward commercial lighting fixtures, and the media channels serving this industry.

c. Architectural Lighting Design Competition

DOE will also explore the development of an architectural lighting design competition, focusing on lighting designs for interior and exterior spaces, as opposed to the fixtures that are the focus of the above design competitions. As with the commercial fixtures design competition, DOE plans first to consult with the IES about potential collaboration in development of this design competition. Its purpose would be to draw attention to the highest quality lighting designs using SSL technology, with special emphasis on designs that take advantage of the unique characteristics of LEDs, and result in significant energy savings relative to conventional lighting technology.

To the extent possible, DOE will attempt to link winners of the residential and commercial fixture design competitions with other projects, especially within the DOE portfolio. One example of this would be to explore the potential for using winners from the fixture design competitions in the demonstration/procurement projects discussed below.

d. State-of-the-Art LED Luminaire Showcase

To draw attention to the significant technical progress being made with LED luminaires, DOE will organize a state-of-the-art LED luminaire showcase, in which luminaire manufacturers and their LED manufacturer partners will be periodically invited to submit proposals to DOE for products they would like highlighted. The showcase would consist of a traveling display illustrating state-of-the-art products, which would be shown at various high visibility lighting industry events, as well as in related descriptive printed and electronic materials. DOE will make a significant effort to seek publicity for products in the showcase, aimed primarily at lighting industry trade media. By prominently featuring state of the art products for the lighting industry, DOE hopes to encourage the lighting fixture industry to aggressively develop new generations of LED luminaires.

3) Technology Demonstrations/Procurements

Market Need: *Highly visible examples of model SSL general illumination applications (to illustrate the practicality and cost effectiveness of SSL)*

DOE proposes to conduct two general types of technology demonstrations: those that demonstrate market readiness, and those that evaluate field performance.

a. Demonstrations of Market Readiness

These demonstrations will seek to work with products whose technical risks of use are low and whose performance is high, yet face market resistance simply because they are new to the market and use an unfamiliar technology. DOE intends to couple these

demonstrations to follow-up activities aimed at achieving significant sales of successfully demonstrated products.

DOE will minimize technical risks and unsuccessful demonstrations through careful selection of candidate products, limiting participation to only those exhibiting high potential of performing well in the field. Prior to field installation, DOE will subject candidate products to a range of rigorous laboratory tests and technical reviews. Only after receiving acceptable results from these evaluations and tests will DOE proceed with field installations. Long-term laboratory testing for lumen depreciation will continue in parallel with field tests. Given the long hours required for this type of testing, lumen depreciation test results will not be available before completion of field testing (but will be so soon after).

In general for these projects, DOE will:

- identify target product categories for demonstrations;
- issue a solicitation for proposals to candidate manufacturers;
- evaluate proposed products to assess their quality and performance, including verification through laboratory testing;
- conduct laboratory lumen maintenance testing that will run concurrently with field testing;
- identify candidate project hosts who would be highly motivated to follow up a successful demonstration project with significant direct purchases or product promotion;
- install products in host facilities;
- measure and evaluate field performance;
- prepare and issue project report, and finally;
- use the demonstration to leverage significant follow-up sales and product promotion.

Via the strong linkage with follow-up promotion and sales activity and careful selection of projects with potential for high visibility and impact, DOE intends to achieve more direct market impacts with this type of demonstration project than is typically achieved with technology demonstrations.

DOE's first project utilizing the above approach is in its early development phase. It is targeting LED products that represent a step-improvement in performance above current LED products, and that offer potential to significantly out-perform conventional products.

b. Demonstrations to Test Field Performance

The second type of demonstration planned by DOE is more traditional, in that its purpose is to observe and measure field performance of advanced LED lighting prototypes. For example, products investigated under this activity may be integrated into automatic lighting control systems, or may use LEDs placed in nontraditional light source locations that lower the need for ambient lighting. These technologies will have inherently higher

technical risks than those addressed in the *Part a.* demonstrations described above. These demonstrations will be used to help SSL product manufacturers and lighting professionals to learn about use of advanced SSL products, and to explore the boundaries of how small, low-voltage, high intensity light sources can be used to significantly reduce lighting energy needs. Manufacturers can learn how field conditions and operation affect the performance of their products, and lighting professionals can gain a better understanding of issues encountered in lighting designs using advanced SSL technologies.

In general for these projects, DOE will:

- identify target product categories for demonstrations;
- issue a solicitation for proposals to candidate manufacturers;
- evaluate proposed products to assess their quality and performance, including verification through laboratory testing;
- install products in host facilities;
- measure and evaluate field performance, and;
- prepare and issue project report whose focus will be identification and evaluation of issues that advance the understanding of using LED systems in general illumination applications.

4) Commercial Product Testing Program

Market Need: *Independent performance test results on commercially available products (to overcome widespread confusion on actual product performance)*

DOE intends to conduct a SSL commercial product testing program to serve three purposes: (1) to provide market feedback data to its SSL R&D program, (2) to collect information useful for developing, evaluating and improving standardized test procedures for SSL equipment, and (3) to provide accurate, objective product performance information to SSL buyers.

DOE launched the SSL commercial product testing program in the first quarter of FY07. The program broadly monitors SSL general illumination products available in the market, and identifies products that are high priority targets for testing, weighing a number of factors intended to serve the three purposes of the program described above. Products are purchased and then tested by one of several contractors arranged to assist this program. Tests include a number of electrical, photometric, and colorimetric measurements. Manufacturers of tested products are given an opportunity to comment on test results prior to their finalization. Testing results, summaries, and interpretations are distributed in both hard copy and via the DOE SSL website.

The testing conducted to date has already revealed important technical issues, including power consumption by LED luminaires in the off state, and the need for better definition and standardized procedures for rating the performance of individual LED packages.

Issues identified through the testing program will feed into the standards development process and the ENERGY STAR program.

This program will be continued and expanded in the following ways:

- The number of products tested per quarter will increase from 5-10 to 10-20, subject to budget constraints, product availability, and program needs.
- Once a substantial collection of test results are available, the profile of the program will be ramped up through promotional efforts, wider distribution of program materials, and linkages with related lighting and energy efficiency programs.
- Reports based on analysis of accumulated test results will be periodically prepared to identify important trends and issues needing consideration by DOE and other entities interested in monitoring the performance of commercial SSL products.

DOE anticipates the program will operate for 3-5 years, during which time DOE will seek both management and financial involvement from partners valuing products from the program, such as energy efficiency program sponsors. During that time, DOE will investigate with its partners various options for longer term operation of the program, should those partners agree there is value in it. Options to be considered include incorporation of the program into a self-financing element of the ENERGY STAR program, similar to the approach DOE has taken with incorporating the testing responsibilities of PEARL within the ENERGY STAR CFL program.

5) Technical Information

Market Need: *Objective, widely available technical information from a credible, respected source (to help fill information gaps and clear up widespread misunderstanding of the technology, its attributes, and its limitations)*

a. Technical Information Development and Dissemination

DOE will implement a multi-faceted technical information effort whose purpose is to inject high-quality, objective, impactful information into the emerging SSL market such that buyers can make better SSL purchasing decisions. Information materials developed for this effort will primarily be oriented toward potential buyers of SSL systems and to the organizations that develop technical information and purchasing guidance for those buyers, such as electric utilities. These materials will not be aimed at general consumers. Instead, they will be aimed at facility managers, energy managers, lighting professionals, and organizations that develop technical materials for residential and commercial buyers, such as electric utilities.

Included among the technical information to be developed and distributed by DOE will be:

- Fact sheets on key technical issues
- Explanations of SSL technology (technology primers)
- Lighting applications issues unique to SSL systems

- Buying guidance
- Lighting application/design guidance
- Technology demonstration reports
- Selected experience/knowledge base for SSL installations
- Peer-reviewed journal articles
- Trade press articles
- Conference papers and presentations

DOE's technical information will be posted on the commercialization support section of DOE's SSL website http://www.netl.doe.gov/ssl/. These materials will help serve participants in the technical information network and others. Materials posted on the website will be regularly updated and expanded, creating a rich, highly useful collection of technical information.

In addition to the website, DOE will produce a range of printed technical materials, focusing on two-page fact sheets and other short printed formats useful for distribution at conferences and meetings.

b. Technical Information Network for Solid-State Lighting

To maximize the effectiveness of this effort, DOE will rely heavily upon a voluntary Technical Information Network of organizations with established, effective outreach programs in key lighting markets. Creation of the network is based upon the idea that is far more cost-effective and impactful to leverage existing, well-established information channels than to create new ones. Organizations and companies DOE expects to participate in this network include electric utilities, regional market transformation organizations, state energy offices, and other operators of energy efficiency programs.

The network will be structured to educate participants about SSL technology and key issues in its effective application. This is a critical step in development of the market in a way that maximizes energy efficiency and quality. The network's members will go through a core curriculum to attain a firm grasp of the technical issues and challenges unique to SSL.

DOE issued a solicitation for proposals to participate in this network in late FY06. Awardees (who will enter into cooperative agreements with DOE) will be expected to help build the network, help develop appropriate information materials for selected target markets based on technical material provided by DOE, and help distribute this information to those selected target markets. The Network will meet at least quarterly.

Depending upon experience in operating the SSL Technical Information Network and the receptivity of its members, DOE will consider expanding the role of the network to include joint development of projects, such as technology demonstration projects.

6) Standards and Test Procedures Support

Market Need: *Industry standards and test procedures for SSL general illumination products (to enable basic market infrastructure)*

When DOE initiated its SSL commercialization support efforts in FY06, there were no industry standards or test procedures for SSL general illumination products. Knowing the importance of standards and test procedures for the successful commercialization of the technology, an intensive effort was initiated to organize and support the organizations with responsibilities for developing these standards and test procedures. Much progress has been made since the March 1, 2006 launch of these efforts, but to date, a small set of high priority standards and test procedures are not yet final, and additional, next-tier standards and test procedures need to be developed.

The primary responsibility for developing these standards and test procedures rests with the industry standards organizations, such as NEMA, IESNA, and UL, but DOE will offer support for the purpose of speeding standards development, and will focus on those standards and test procedures needed to achieve SSL's energy saving potential. DOE plans to continue to support these efforts with national meetings, coordination assistance, technical assistance, and laboratory testing.

7) Coordination/Leadership

Market Need: *Coordination of local, regional, and federal SSL commercialization activities (to maximize effect of invested public and ratepayer money)*

a. Facilitating and Coordinating Local and Regional Efforts

A large number of electric utilities, state energy offices, state RD&D organizations, and regional energy efficiency programs operate programs to promote the deployment of emerging energy-efficient technologies. The cumulative program resources available to these organizations greatly exceed those of DOE. However, most of these organizations have not yet developed programs that address SSL. DOE could help catalyze activity among these organizations, first by providing much needed technical information on the technology (which is proposed as part of the SSL Technical Information Network), but also by proposing joint projects, providing opportunities for collaboration, and by convening meetings and conferences.

DOE's expertise with SSL technology, its national mission, and its reputation for technical excellence position it well to provide the national leadership to leverage additional SSL commercialization support activity.

b. Federal Government Leadership

A key means by which DOE can provide leadership and catalyze activity in other government funded programs is to stimulate SSL adoption within the federal sector.

The Buildings Technology (BT) Program needs to work closely with the Federal Energy Management Program for this element. Joint BT/FEMP activities could include collaboration on demonstration projects, educational seminars, presentations at FEMP meetings and conferences, development and distribution of technical materials designed specifically for the federal sector, technical assistance for model projects, and others.

Task Areas and Their Interrelationships

Each of the strategic elements of the plan described above comprises a task area. Those task areas and their relationships to each other are described here. The task areas are organized to exploit three primary market interfaces, each providing a distinct approach for working with manufacturers, interacting with buyers, and ultimately accelerating movement of high-efficiency products into the market place. These three pathways – Buyer Guidance (e.g., ENERGY STAR), Design Competitions (e.g., Lighting for Tomorrow), and Technology Demonstrations/Procurements – are complementary, and collectively provide a comprehensive approach to commercialization support. They are supported by a set of crosscutting task areas that provide a range of important services to the pathways.

Figure 1 illustrates the relationship of the proposed task areas to the SSL program, SSL MYPP goals, market, and each other. As seen, the three market interfaces are the central elements of the commercialization effort. They are positioned at the critical juncture between manufacturers and buyers, leveraging DOE's unique identity, reputation for objectivity, and resources to accelerate the rate at which the market demands high performance SSL devices and the rate at which manufacturers commercialize these products. Positioning DOE's efforts in this manner allows DOE to offer valuable assistance to both manufacturers and buyers, as indicated in the value streams. Likewise, it allows DOE to obtain valuable information and collaboration from buyers and manufacturers. Supported by the crosscutting task areas at the bottom of the figure, the three market interfaces are the primary channels through which the SSL program seeks to influence what manufacturers produce, and what buyers purchase. The distinguishing characteristics of these three market channels are:

Buyer Guidance (e.g., ENERGY STAR) – mass market oriented; unique brand; used to guide buyers to higher performing, energy-efficient products; strong emphasis placed on working with retailers, distributors and energy efficiency program sponsors

Design Competitions (e.g., Lighting for Tomorrow) – industry oriented; unique brands; primarily used to support new product introductions; strong emphasis on aesthetic design to make products attractive to buyers; strong emphasis on collaborating with lighting retailers, fixture manufacturers and lighting professionals

Technology Demonstrations/Procurements – target market oriented; no branding; supports new product introductions; strong emphasis on collaborating with high volume buyers and energy efficiency program sponsors

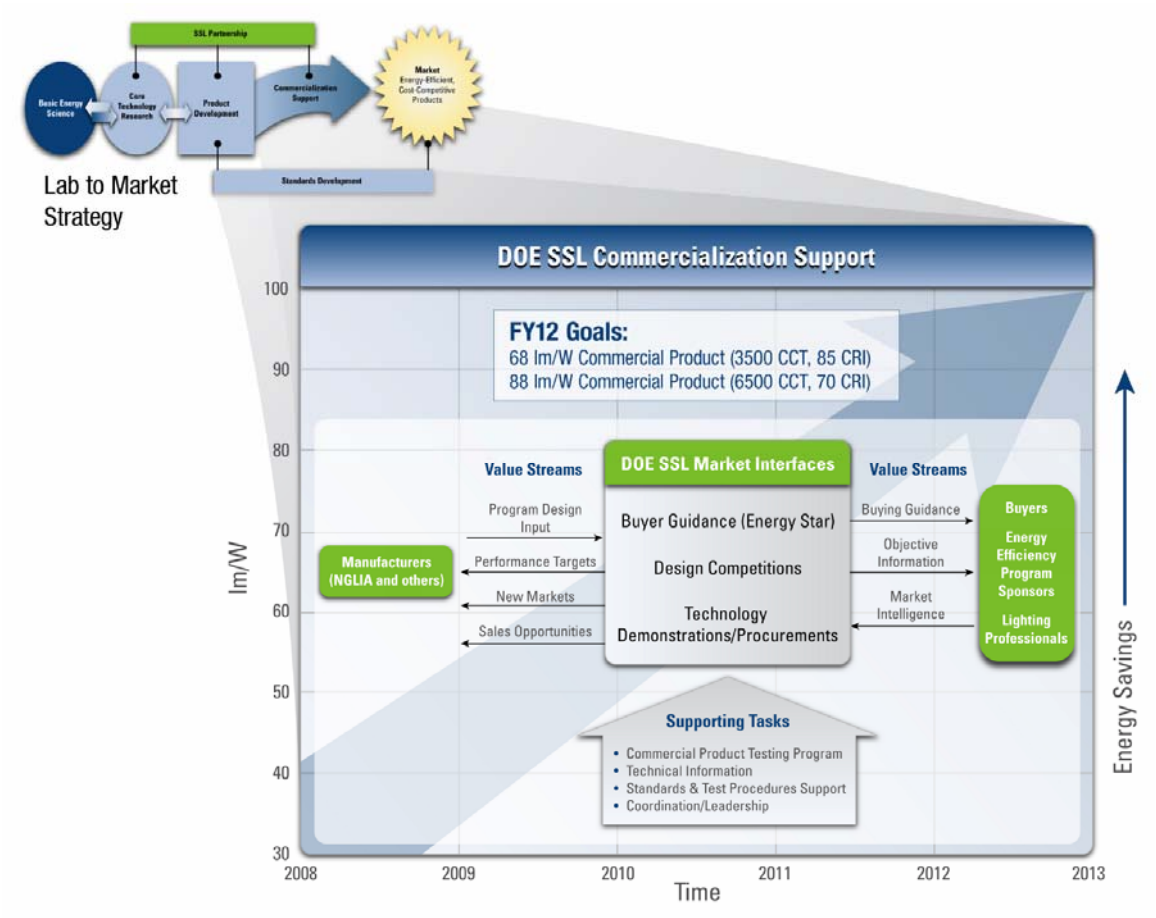


Figure 1. Relationship of task areas to SSL Program, SSL MYPP goals, market, and each other.

The supporting task areas provide valuable services to the above market interfaces, in multiple and interrelated ways:

Commercial Product Testing Program – needed to verify product performance claims, provide consumers with reliable third-party product information, and inform test procedures and standards; supports:

- Buyer Guidance by providing performance information directly to buyers and those who work with buyers
- Design Competitions by helping judges evaluate products submitted in competitions
- Technology Demonstrations by providing useful laboratory performance information on products to be tested in field demonstrations

Technical Information – delivers important information into the hands of buyers – and those who influence them – to help them make better purchase decision; supports:

- Buyer Guidance by providing a range of technical information primarily of use to energy efficiency program sponsors (who use them to develop program designs and materials for their customers) and large facility managers
- Technology Demonstrations/Procurements by helping large volume buyers in those projects better understand SSL technology

Standards and Test Procedures Support – accelerates development of standards and test procedures that support application of SSL to the general illumination market; supports:

- Buyer Guidance by helping develop the test procedures and standards that are necessary for ENERGY STAR specifications and design/purchasing guidelines
- Design Competitions and Technology Demonstrations/Procurements by making possible the standards and test procedures needed to properly evaluate product performance

Coordination/Leadership – helps organize and leverage the substantial resources of the federal government and energy efficiency program sponsors; supports:

- Buyer Guidance by improving the effectiveness with which energy efficiency program sponsors can use ENERGY STAR
- Design Competitions by expanding involvement in and awareness of design competition results
- Technology Demonstrations/Procurements by helping identify potential partners for projects and by expanding involvement in and awareness of projects

Key Issues to be Addressed in Project Development

The preceding section described the key elements of DOE's SSL commercialization support strategy. These elements will be used to guide development of projects that flow from the plan, some of which will be short-term, others may last the entire five year life of this plan. This section identifies a number of high priority issues DOE plans to consider when developing these projects.

1. *Early, low- performing SSL products are likely to cause substantial and lasting market damage. (First impressions are important.)*

As occurred with compact fluorescent lamps and described in the report, *Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market*, early generation, new technology lighting products can cause long-term market damage (DOE, 2006c). Disappointed buyers of those early products are reluctant to try the new technology again, even if it has been improved, and share their disappointment with other potential buyers, both of which can lead to long-term market damage.

2. *High costs*

High quality, high brightness LEDs currently sell for roughly 40 times more than fluorescent lighting when measured on a per kilolumen basis. DOE projects this

difference will continue to decline rapidly, but will remain higher than conventional cost lighting for many years to come. Lighting equipment buyers, however, don't purchase light sources by comparing per kilolumen costs. They use such measures as simple payback and lifecycle costing. Careful analysis of the economics of using SSL for individual general illumination applications will be necessary to help guide program planning and project designs.

3. Low color quality/high color correlated color temperature (CCT)

An oft heard complaint of early generation CFLs was they didn't produce warm light and they made skin color look unnatural. This widely held view didn't die out when warm color, high color quality CFLs became available. Reporters and consumers continue to refer to "harsh, cold fluorescent lighting" as if the technology hasn't changed and by definition, fluorescent means poor quality lighting. A recent Wall Street Journal article on CFLs described the persistence of this view, and how it continues to hinder sales of CFLs long after CFLs with good color quality became available in the market.[4]

Similarly, most early versions of LEDs being introduced as general illumination products use high-CCT, low-CRI LEDs because they are more efficacious than their warm white counterparts. These products may be defining LED products to the market for a whole generation of potential users, creating the possibility that like fluorescent lamps, LEDs will mean cold, unattractive light for a significant number of potential buyers.

4. Incomplete standards, test procedures

One of DOE's first efforts in helping commercialize SSL products was offering its assistance to the SSL industry for developing a number of industry standards and test procedures. As of December, 2006, four key standards and test procedures were under development. The specific procedures selected were identified by DOE and the SSL industry as having the highest priority for early completion. However, a number of other standards and test procedures are still needed, and until they are complete, the industry will continue to encounter problems that limit growth of the SSL industry. Among those still needed are those addressing interconnections between system components, LED device and LED array efficacy, and perhaps test procedures for low-cost methods to measure luminous flux from residential SSL luminaires.

5. Will SSL lead to profligate use of lighting?

LEDs' small form factor, low-voltage circuits, and high durability, as well as high potential to become much less expensive and much more efficient combine to create the possibility of a future in which new applications for lighting become so numerous, and LED lighting so ubiquitous, that SSL technology could in the long run lead to more lighting energy use rather than less.

---

[4] "Philips Pushes Energy Saving Bulbs: Why this Bright Idea is a Hard Sell," Wall Street Journal, Dec. 5, 2006.

6. Quick obsolescence

The speed of technology improvement for LEDs creates special challenges for their market introduction. Similar to computer hardware during the 1990s, technological improvements for LEDs are being introduced so quickly that systems become obsolete long before the end of their physical lives. So how important is it for LED systems to have physical lives in the tens of thousands of hours when products being introduced to the market one year or 18 months later may be twice as efficient? Should LED systems have easily replaceable parts knowing that in most cases, users will be better off replacing the entire LED system upon component failure? Should product specifications and standards require physical lives longer than economic lives?

7. *Retrofit products*

Many of the early LED general illumination products introduced to the market were designed to imitate the function of incandescent lamps, and thus could be retrofit into lighting fixtures designed for incandescent lamp use. These products were generally poorly designed, from both a thermal management and optical perspective. They didn't (and couldn't) use light fixtures into which they were installed as part of their heat sink, and they cast light in all directions, causing significant light loss within the fixture and forfeiting one of the inherent efficiency advantages of LEDs. In short, the limitations of current technology present very substantial challenges for designing LED products to be retrofit into existing fixtures.

But that is likely to change as technology improves. Manufacturers steadily introduce products with much higher maximum operating temperatures than previous LED generations. Products designed with these LEDs face far less challenging thermal management design difficulties, potentially enabling future LED retrofit products that won't need to use the fixture as part of the thermal management system. In addition, the unrelenting pace of efficacy improvement means that LED retrofit products will eventually be so efficient that significant light losses within the fixture may still leave an LED-retrofitted fixture a more efficient option than a fluorescent-retrofitted fixture.

In addition, a lesson learned from the many years of utilities promoting CFL fixtures is also applicable here: While a fixture specifically designed for using CFLs is typically more efficient than an incandescent fixture retrofit with a CFL, consumers have overwhelmingly chosen to retrofit CFLs into existing fixtures rather than buy CFL-dedicated fixtures. Among the reasons consumers choose screw in CFLs over CFL fixtures is they cost less, they like their existing fixtures, and they like the flexibility of being able to revert back to another light source if they don't like the CFL. Many existing fixtures are an important aesthetic part of a living space, and consequently, consumers don't easily part with them. We can expect a similar reaction to new LED fixtures. When faced with the choice of buying a dedicated-LED fixture of high efficiency or retrofitting an LED system into an existing fixture of modest efficiency, we can expect a large fraction of consumers to choose the latter.

9. Commercial vs. residential luminaire emphasis

As indicated in the Purpose, Goals, and End State sections above, DOE plans to strongly emphasize those SSL applications likely to produce significant energy savings. This raises the question of whether to focus efforts on the residential or commercial sector. While commercial lighting dominates U.S. lighting energy use, and thereby represents a much larger potential energy savings target, residential lighting nonetheless represents a significant energy saving opportunity for SSL because:

- incandescent lighting is the dominant light source in the sector, a very inefficient source relative to fluorescent and SSL technology;
- required levels of luminous flux from fixtures is modest due to generally lower ceilings and smaller spaces (which is consistent with the lower flux capabilities of SSL's near-term state of technical development), and;
- SSL's dimming capabilities compete well with fluorescent lighting, the primary energy-efficient alternative to SSL. (Compact fluorescent dimming products tend to be difficult to find in retail stores, are significantly more expensive than non-dimming products, and often don't perform well enough to meet consumer expectations.)

However, the commercial market remains the leading candidate for SSL products because:

- electricity costs are generally higher than in the residential sector, and lighting hours of operation are much longer, making the economics of SSL more compelling;
- commercial customers tend to be more sophisticated lighting buyers, and pay more attention to cost-effective lighting investments;
- labor costs for replacement and maintenance are often monetized, making LED durability and long life more attractive, and;
- commercial customers are generally more receptive to lighting products with higher first costs than other alternatives.

DOE will closely monitor changing economics for both commercial and residential applications, as well as changes in the technology affecting SSL's suitability for various applications. Resources will be focused on lighting applications and projects most likely to maximize potential U.S. energy savings.

10. Likely near-term target lighting applications

Near-term general illumination applications that are both technically appropriate and economically feasible for SSL technology will likely exhibit the following characteristics:

- total lighting flux requirements are low to moderate;
- the application can take full advantage of SSL's directional light, thereby minimizing optical losses in fixtures;

- higher color temperatures acceptable or advantageous;
- fixtures are operated a large number of hours per year;
- high value can be derived from SSL's potential for long life, and therefore low maintenance costs;
- dimming or ability to withstand frequent switching is important;
- fixtures are subjected to constant or frequent low ambient temperatures;
- low or no emissions in the infrared and ultraviolet range are important;
- small form factors are valuable, and;
- the incumbent light source technology for the application has significant shortcomings, such as inefficiency or poor color quality.

DOE will develop and maintain a list of applications consistent with the above characteristics (and other characteristics identified after adoption of this plan), and include those under the economic analysis described in Point 9 above.

Performance Measurement

Progress towards the goals of this plan will be assessed using a set of quantitative and qualitative metrics. Measurements will be made at least annually, and more frequently should conditions require it. Results from these measurements will be used to update and modify the plan, improving the quality and effectiveness of its activities. These measures will also be used to facilitate early identification of problems so that timely corrections can be made while any issues are still minor.

DOE will seek commitments from its SSL Commercialization Support partners and contractors to work toward the goals of this plan and take responsibility for ensuring satisfactory progress. At a minimum, DOE will pursue commitments from:

- Next Generation Lighting Industry Alliance
- Pacific Northwest National Laboratory
- Akoya, Inc.
- Organizations that have signed cooperative agreements under the SSL Technical Information Network

The performance metrics and underlying information for each include:

1) Identification and documentation of top-performing general illumination commercialized SSL products

- Device efficacy (luminous efficacy), luminaire efficacy, CCT and CRI if available from manufacturer; verify with independent laboratory testing
- Description of intended lighting applications
- Description of market availability (e.g., where offered for sale, through what channels, evidence of installations, references in lighting media, etc.)

- Data collected via active monitoring of trade media, manufacturers communications, conference proceedings, laboratory testing, and survey instruments

2) Annual sales of ENERGY STAR compliant SSL products
   - ENERGY STAR compliance representing the baseline of high-performance products
   - Voluntary sales reporting from ENERGY STAR manufacturer partners
   - Identification of intended lighting application by sales category; these numbers will be compared to sales of conventional light sources for these lighting applications to estimate fraction of sales due to SSL products.
   - In addition, DOE has entered into an agreement with the National Electrical Manufacturers Association (NEMA) to collect and analyze SSL sales data. DOE will have NEMA track and document ENERGY STAR sales as part of this contract.

3) Annual energy savings achieved
   - Annual energy savings calculated as the difference between energy savings due to a "natural rate" of SSL market adoption and energy savings due to an accelerated rate of market adoption.[5]

Annual measurements for all three of the above metrics will be completed by March 1 for each year covered by this plan.

Schedule

A schedule of key outcomes, by task, by fiscal year is attached as Attachment A.

Partnerships

---

[5] The "natural rate" of SSL market adoption would occur in the absence of a DOE SSL program. It is not directly measurable, or easily estimated because DOE has already made five years of substantial investments in SSL technology, thus already affecting the rate at which SSL general illumination products are being developed and sold.

Based on findings from a National Research Council evaluation of DOE energy research, DOE is estimating its investment in SSL is accelerating the market adoption of the technology by five years. The natural and accelerated market adoption curves are parallel, but offset by five years. The accelerated rate market adoption curve is deemed to be that curve estimated in a recent DOE energy savings estimate (DOE, 2006). The natural rate adoption curve is deemed to be the accelerated curve, plus five years. DOE will collect market data to support annual updates of its SSL energy savings estimate, using the same methodology used for its 2006 energy savings estimate.

DOE has identified the following key partners whose cooperation will be important to successful implementation of this plan. The resources, expertise, and networks these program partners bring to the efforts represented by this plan greatly multiply any market development DOE can achieve on its own.

This plan will be shared with them, and to the extent possible, DOE will seek agreements solidifying their cooperation in helping implement elements of this plan. In addition to many special purpose meetings that will be held with these partners, DOE plans to hold an annual SSL Commercialization Support Workshop whose primary purpose will be to solicit involvement and guidance on projects carried out under this plan, as well as the plan itself. The first of such workshops is already planned for April 23 and 24, 2007 in Southern California.

Key Partners (not listed in order of priority)

1) Federal Energy Management Program
2) Energy Efficiency Program Sponsors, especially those which have partnered with the ENERGY STAR program (utilities, energy efficiency organizations, and state agencies)
3) Building America
4) U.S. Green Building Council
5) Next Generation Lighting Industry Alliance
6) Illuminating Engineering Society of North America
7) American Lighting Association
8) International Association of Lighting Designers
9) National Association of Lighting Distributors
10) National Electric Manufacturers Association
11) American National Standards Institute
12) Underwriters, Inc. Laboratories (U.L.)

Attachment A

KEY OUTCOMES BY FY							
	Market Interfaces	**Pre-Plan Year 07**	**08**	**09**	**10**	**11**	**12**
1.0	**Buying Guidance**						
1.1	Energy Star Criteria	Final Criteria	Vers 1.1, 1.2	Vers 1.3, 1.4	Ver 2.0	Ver 2.1	Ver 2.2
1.2	Federal Design/Purchasing Guidance	-	New Guidance	Update	Update	Update	Update
2.0	**Design Competitions**						
2.1	Lighting for Tomorrow	07 Comp	08 Comp	09 Comp	10 Comp	11 Comp	12 Comp
2.2	Commercial Fixtures	Project Design	08 Comp	09 Comp	10 Comp	11 Comp	12 Comp
2.3	Lighting Design	Project Design	08 Comp	09 Comp	10 Comp	11 Comp	12 Comp
2.4	State-of-the-Art Showcase	Project Design	08 Comp	09 Comp	10 Comp	11 Comp	12 Comp
3.0	**Demonstration/Procurements**						
3.1	Market Readiness Demonstrations	2-3 Demos	3-4 Demos	3-4 Demos	3-4 Demos	3-4 Demos	3-4 Demos
3.2	Field Test Demonstrations	-	1-2 Demos	1-2 Demos	1-2 Demos	1-2 Demos	1-2 Demos
	Supporting Task Areas						
4.0	**Commercial Product Testing Program**						
4.1	Commercial Product Testing	20-30 Tests	40-50 Tests	40-50 Tests	Self-suppt spin-off	-	-
5.0	**Technical Information**						
5.1	Technical Information Dev. & Dissemination	new website	Dev/Dissm 4 Prod	Dev/Dissm 4 Prod	Dev/Dissm 4 Prod	Dev/Dissm 4 Prod	Dev/Dissm 4 Prod
5.2	Technical Information Network Mtgs/Coord	launch network	4 Qrt. Meetings	4 Qrt. Meetings	4 Qrt. Meetings	4 Qrt. Meetings	4 Qrt. Meetings
6.0	**Standards and Test Procedures Support**						
6.1	Standards and Test Procedures Support	6 new std	2 new std/2 update	1 new std/2 update	1 new std/2 update	1 new std/1 update	-
7.0	**Coordination/Leadership**						
7.1	Local and Regional	-	2 joint projects	2 joint projects	2 joint projects	2 joint projects	2 joint projects
7.2	Federal Government	-	1 major fed action	1 major fed action	1 major fed action	1 major fed action	1 major fed action
	Project Management						
	Management	-	meet proj goals	meet proj goals	meet proj goals	meet proj goals	meet proj goals
	Project Analysis and Planning	as assigned	as assigned	as assigned	as assigned	as assigned	as assigned
	Progress Measurements	-	annual report	annual report	annual report	annual report	annual report
	Annual Comm. Support Workshop	-	annual workshop	annual workshop	annual workshop	annual workshop	annual workshop

References

NRC, 2001. Energy Research at DOE: Was It Worth It? Prepared by Committee on Benefits of DOE R&D on Energy Efficiency and Fossil Energy, National Research Council, National Academy Press, Washington, D.C., 2001.

DOE, 2006. Energy Savings Potential of Solid State Lighting in General Illumination Applications, Final Report. Prepared for Lighting Research and Development, Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. Prepared by Navigant Consulting, Inc., U.S. Department of Energy, Washington, D.C., December, 2006.

DOE, 2006b. Solid-State Lighting Research and Development Portfolio Multi-Year Program Plan, FY 07-12, U.S. Department of Energy, Washington, D.C., March 2006.

DOE, 2006c. Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market. Prepared for U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program. Prepared by Pacific Northwest National Laboratory. U.S. Department of Energy, Washington, D.C., June 2006.

APPENDIX D: Case Studies 1-5

Voices for SSL Efficiency:
Opportunities to Partner and Participate
July 16-17, 2007 ■ Boston, MA

DETAILED CASE STUDY FOR BREAKOUT SESSIONS

Integrated SSL Table Lamp

A core activity of the DOE SSL Market Introduction Workshop will explore case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees will participate in one of the five case study breakout sessions.

This exercise is a vehicle for determining how DOE commercialization plan elements will best support the market introduction needs of new SSL products. It will serve to identify major stakeholders and the elements of the DOE programs where their participation will be most valuable. And it will provide valuable feedback to improve the design of DOE programs.

The Assignment
Each breakout group will consider one case study, working together to:

- Outline a general strategy to sell their target product, identifying issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

The case studies include a lot of questions, provided to help you think about the issues. Some may apply, and some may not. The group doesn't need to address all the questions, but should address the questions and issues that are most important for this case study.

Case Study Structure
Each case study includes:

- An Introduction that identifies the product and places it within its intended market segment, outlining competitive advantages and disadvantages.
- The Product Description offers additional detail on performance.
- Pricing further defines the market served.
- Other Considerations are things the group may want to think about specific to this product.

Please note: The case study products are ***hypothetical*** products with ***plausible*** performance parameters (or that's the intention). In many cases, they would be technically challenging to produce today, but that doesn't matter for this exercise. Don't worry too much about the performance or market numbers, or spend time re-designing the product. This information is provided in the case studies only to help you understand the issues related to this product.

SSL Market Introduction Workshop
Breakout Case Study #1

Integrated SSL Table Lamp

Introduction: The target product is an integrated SSL table lamp intended for residential use. This product is intended to compete with incumbent portable residential light fixtures of similar types having a 100W incandescent light source. Pricing is such that there is a clear economic advantage arising from the energy savings when compared to either an incandescent or compact fluorescent (CFL) conventional product, although the former is obviously more dramatic. Principal issues in selling this product, and hence important aspects of the marketing plan, may revolve around skepticism as to the advertised lifetime or concerns about the fully integrated design which does not permit changing the light source, i.e., "no customer-repairable components within". There may also be some difficult sales channel issues.

Product Description: Luminaire efficacy of the table lamp, as an integrated fixture, is about 50 LPW. Most of the light is directed in an upward or downward direction by design to improve the efficiency while still offering a table lamp "flavor." This is in contrast to the performance of a conventional table lamp, which has a similar appearance to the new product, but a great deal of light is trapped within the shade, reducing the overall efficiency. Although the "advertised" efficacy of the typical 100W replacement light bulb is approximately 15 LPW, it is reduced to less than 10 LPW when installed in the fixture, making the new SSL table lamp about five times as efficient as a conventional lamp, and it uses only about 15W. The solid-state LED light source is built into the product, is not replaceable, and it lasts the life of the product, about 15 years. The integrated design includes a dimmer, as this feature requires special-purpose electronics for best performance. The LED table lamp is available in a number of design variations intended to address the "middle" of the residential consumer lighting market.

Pricing: The average conventional portable table lamp sells for approximately $25, exclusive of the incandescent lamp, which is approximately $1 per lamp. The light bulbs have a life of about one year in typical residential use (1000-1500 hours), so they will need replacement at least annually. The new product is premium-priced at about $40, which is intended to make the product competitive with traditional products when taking energy savings and lamp life into account.

Other Considerations: This product is designed to appeal to the energy-conscious consumer. As such, alternative competition is available: the consumer could buy a conventional table lamp light fixture and CFL replacement bulbs instead of the integrated fixture. How would this work out? CFLs cost around $4 per lamp and last for 5 years. So the light source replacement cost using CFLs is, over 15 years, around $12 relative to $15 for incandescent replacements. Thus, CFLs are *marginally more attractive* than incandescent on a first-cost basis. What about energy savings? The CFL has a system efficacy of 55 LPW (lamp plus ballast only), yielding only about 30 LPW luminaire efficacy, *still considerably less attractive* than the LED fixture (but much closer to the LED fixture than is the incandescent).

The Market: Approximately 40 million table lamps are sold in the U.S. in a year. Most portable fixtures of this type are selected and purchased directly by the consumer, in contrast to built-in type fixtures, which may be selected by a contractor or builder with perhaps only limited input from the end customer. This product, with its available design variants, can address about one

fourth to one third of the available market – say 10-15 million units' addressable market. Table lamps are sold through a variety of sales channels, including department stores, home improvement outlets, and specialty lighting shops. In contrast, the replacement bulbs are mainly sold through grocery and drug stores, hardware chains, and mass merchandisers. With the long life of the integrated SSL table lamp, several of these conventional outlets will be left out and more sales volume will accrue to the traditional light fixture sales channels.

The Assignment

Your Job: Your assignment is to design a marketing strategy for this product. Trade-offs in price, energy savings, and color quality will need to be addressed in a constructive way. The marketing strategy will need to address quality and pricing issues squarely in dealing with a complex combination of decision-makers. Your company, a mid-sized manufacturer of lighting fixtures, has many years of experience with traditional lighting and many relationships along the value chain, but this is your first SSL product. DOE has developed a plan that will involve many public organizations such as government agencies, utility companies, state energy efficiency organizations, industry organizations, and others. They have begun important educational, technical support, and standardization activities intended to accelerate market development. Most activities, however, are not directed at any particular market segment or product type. An important aspect of this market development exercise is to determine how you can most effectively use these programs to achieve your goals. How should DOE or the other organizations apply or improve these programs to best support the needs of this target product and market?

The Task, Part I: Frame the general outlines of the marketing strategy.

- Where are the weaknesses in the incumbent products that can provide new opportunity? What are the key competitive barriers to success? What are the technological barriers to success?
- How can you best exploit the energy savings inherent in this product to foster market acceptance?
- What has to happen for a successful market introduction of an energy-efficient residential-use table lamp? Define "success." What are your sales goals for the first year or two?
- What segments or niches of this residential market might be particularly appropriate for initial attention? Who are the influencers in these segments?
- What buyer behaviors will need to change in order to achieve success? What are the barriers to these changes? How can you address them?
- What are the appropriate sales channels? How will you deal with your traditional sales that may be left out in the new paradigm? What changes will the targeted sales channels see?
- What other barriers do you perceive to marketing of this product?

The Task, Part II: Identify the roles of the government and non-government agencies and organizations. What market introduction options could DOE (and its partners) initiate?

- In the table below are listed some potential market-assisting activities that many public and industry organizations may be willing to support. Which do you think would be most useful? How would you apply these activities to your overall plan?
- Which activities are not useful for this particular product? Why? Could they be improved?
- What other elements would you add to this list?
- You have heard about the commercialization activities at the DOE. Which elements of the DOE plan would best contribute to your marketing strategy?
- What other groups will be most important to engage to achieve success? With which aspects of your strategy can they most usefully assist?

General Comments and Advice:

- Your team has limited time to put together a solution to this assignment. For best results (and most useful for this workshop) spend only a portion of the first day's breakout session on Part I and do some brainstorming on Part II. Use the second day breakout to complete your evaluation to tidy up your presentation.
- Don't spend a lot of time debating the numbers in the case study. The idea is to give you something concrete to work with, not to give you a review of the lighting market or for you to design a specific product.
- Give your product a name. Make it sell!

Campaign elements	Stakeholders and roles*	How could you use this element for this product?
Buyer Guidance		
a) ENERGY STAR® Criteria		
b) Design/Purchasing Guidance		
Design Competitions		
a) Lighting for Tomorrow (Residential Fixtures)		
b) Commercial Fixtures Competition		
c) Lighting Design Competition for Exterior & Interior Spaces		
d) State-of-the-Art LED Luminaire Showcase		
Technology Demonstrations/Procurements		
a) Demonstrations of Market Readiness		
b) Demonstrations to Test Field Performance		
Commercial Product Testing		
a) Commercial Product Testing Program		
Technical Information		
a) Information Development and Dissemination		
b) Technical Information Network		
Standards and Test Procedures		
a) Standards/Testing Procedure Development Support		
Coordination/Leadership		
a) Facilitating and Coordinating Local and Regional Efforts		
b) Federal Government Leadership		
Other		

* Stakeholders: Standards organizations, manufacturers, industry associations, commercial lighting distributors, residential lighting showrooms, retailers, ESCOs, EEPs, utilities, state energy efficiency programs, large purchasers, energy efficiency advocates, others…

Voices for SSL Efficiency:
Opportunities to Partner and Participate
July 16-17, 2007 ■ Boston, MA

DETAILED CASE STUDY FOR BREAKOUT SESSIONS

Commercial Office OLED Ceiling Lighting Fixture

A core activity of the DOE SSL Market Introduction Workshop will explore case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees will participate in one of the five case study breakout sessions.

This exercise is a vehicle for determining how DOE commercialization plan elements will best support the market introduction needs of new SSL products. It will serve to identify major stakeholders and the elements of the DOE programs where their participation will be most valuable. And it will provide valuable feedback to improve the design of DOE programs.

The Assignment

Each breakout group will consider one case study, working together to:

- Outline a general strategy to sell their target product, identifying issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

The case studies include a lot of questions, provided to help you think about the issues. Some may apply, and some may not. The group doesn't need to address all the questions, but should address the questions and issues that are most important for this case study.

Case Study Structure

Each case study includes:

- An Introduction that identifies the product and places it within its intended market segment, outlining competitive advantages and disadvantages.
- The Product Description offers additional detail on performance.
- Pricing further defines the market served.
- Other Considerations are things the group may want to think about specific to this product.

Please note: The case study products are ***hypothetical*** products with ***plausible*** performance parameters (or that's the intention). In many cases, they would be technically challenging to produce today, but that doesn't matter for this exercise. Don't worry too much about the performance or market numbers, or spend time re-designing the product. This information is provided in the case studies only to help you understand the issues related to this product.

SSL Market Introduction Workshop
Breakout Case Study #2

Commercial Office OLED Ceiling Lighting Fixture

Introduction: The target product is an OLED ceiling lighting fixture intended to provide general illumination for commercial office space. A technology breakthrough funded through the DOE Solid-State Lighting R&D program has made possible the inexpensive production of a high-brightness OLED "tape" light source. While we have traditionally thought of OLEDs as panel lights, the tape configuration minimizes the use of relatively expensive OLED material, while still providing a flexible design platform for broad area lighting. This breakthrough, while significantly improving the competitiveness of the OLED technology, has not yet made it a clear economic winner. The offered OLED luminaire significantly outperforms traditional fluorescent lights with regard to energy, making it very attractive in that regard, but is still only marginally cost effective on the basis of energy savings alone. Both non-energy benefits and energy-related economic incentives will therefore importantly affect your ability to sell this product.

Product Description: This product is aimed squarely at replacing the typical 2x4-foot lighting fixture widely used in office building lighting with strip lighting that can either be incorporated into a panel-like fixture or perhaps a suspended fixture, or could be deployed in imaginative ways about which we can only speculate. Color rendition is excellent, with an index approaching 90, superior to fluorescents. The light source and associated driver are built into a relatively simple fixture; neither source nor driver is replaceable. The useful light delivered from the OLED ceiling lighting fixture is 2400 lumens and it consumes 28W of power (a *luminaire* efficacy of 85 LPW). Although a conventional T8 fluorescent tube is often quoted as having the same 85LPW efficacy, the ballast (fluorescent driver) and the fixture reduce the luminaire efficacy to about 60 LPW. So the new product actually has a 40% energy-savings advantage (85 LPW vs. 60 LPW). The new breakthrough OLED tape-light source lasts the life of the product, which is expected to be about 15 years. This lifetime is comparable to a fluorescent ballast, and much better than the fluorescent tube that requires replacement every 2 years or so.

Pricing: The average single tube commercial-grade fluorescent fixture, including the ballast, costs approximately $40. The lamp cost is a modest $1-2 each but the replacement of them involves not only the cost of the tube but also the cost of labor for the replacement, and the cost of hazardous waste disposal. The new-technology SSL area fixture is priced at $50, significantly above the first cost of the incumbent product, even including the lamp replacement costs over the lifetime. In addition to energy savings, the manufacturer is counting on the better color, labor savings, disposal savings, and the attractive design to justify this cost premium.

Other considerations: Commercial lighting purchasers are more sophisticated than residential consumers, but are still very much focused on the bottom line and usually only willing to consider a two-year payback period or less They are, however, increasingly sensitive to energy savings and will take that into account when considering the economics. Decision-makers are also very concerned about the acceptance of any new lighting technology by the building occupants, and are risk-averse in this respect. Being unfamiliar with actual maintenance requirements, the visual appearance of the light, and so forth, they may resist change. Will they

achieve the advertised energy savings? There is also the issue of reliability. What assurance do buyers have that the new lights will last as long as manufacturers say they will?

The Market: Twenty-five percent of the U.S. annual energy consumption for lighting is consumed in large and small offices. And 80% or more of delivered light in these buildings is provided by fluorescent luminaires of the type addressed by this product. From an energy efficiency perspective this is an important market. Your company's research has identified a target market comprising 20-25 million new units annually. Presently there are additional annual lighting sales of about 300 million fluorescent tubes. This bulb replacement market would largely be supplanted by an OLED light of this sort, which could have an adverse effect on relations with certain distributors. And, these types of fixtures are mostly sold through large distributors, with few exceptions.

Assignment

Your Job: Your assignment is to design a marketing strategy for this product. Your company, a major manufacturer of commercial lighting fixtures, has many years of experience with traditional lighting and many relationships along the value chain, but this is your first SSL product. Fortunately you are addressing a highly motivated market. Both economic and environmental factors are beginning to have stronger influence on buying decisions, with several large corporations beginning to undertake serious energy savings programs. DOE has developed a plan that will involve many public organizations such as government agencies, utility companies, state energy efficiency organizations, industry organizations, and others. They have begun important educational, technical support, and standardization activities intended to accelerate market development. Most activities, however, are not directed at any particular market segment or product type. The main purpose of this part of your market development process is to determine how you can most effectively use these programs to achieve your goals. What changes, if any, might improve these programs to better support the needs of your product and market?

The Task, Part I: Frame the general outlines of the marketing strategy.

- Where are the weaknesses in the incumbent products that can provide new opportunity? How can you exploit them? What are the key competitive barriers to success? What are the technological barriers to success?
- How can you best exploit the energy savings inherent in this product to foster market acceptance?
- What has to happen for a successful market introduction of an energy-efficient OLED ceiling lighting fixture in this segment? Indeed, what is "success"? What might be some useful unit sales goals for the first year or two?
- What other segments of the commercial or industrial marketplace might be also appropriate for this product? What market actions or product changes would make it more useful in or acceptable to these other segments?
- Buyers for large offices have to consider many factors and are risk-averse. What behaviors will need to change in order to achieve success? What are the barriers to these changes? How can you address them? How can government testing or educational programs assist you?
- What sort of issues do you expect to encounter with your distributors? Will you need to develop new sales channels, and if so, what would they be? How will you deal with your traditional sales?
- Is there likely to be a "maintenance issue" for the new technology, given that the entire fixture must be replaced at end of life? Is it important to the marketing of this product?

The Task, Part II: Identify the roles of the government and non-government agencies and organizations.

- In the table below are listed some potential market-assisting activities that many public and industry organizations may be willing to support. Which do you think would be most useful? How would you apply these activities to your overall plan?
- Which activities are not useful for this particular product? Why? Could they be improved?
- What other elements would you add to this list?
- You have heard about the commercialization activities at the DOE. How can the DOE best make a contribution to your market strategy?
- What other groups will be most important to engage to achieve success? With which aspects of your strategies can they most usefully assist?

General Comments and Advice:

- Your team has limited time to put together a solution to this assignment. For best results (and most useful for this workshop) spend only a portion of the first day's breakout session on Part I and do some brainstorming on Part II. Use the second day breakout to complete your evaluation to tidy up your presentation.
- Obviously, this is a very speculative product, given the state of the art of OLED technology today. The trade-offs in cost, brightness, and lifetime are difficult; we have simply postulated that the problems have been solved, as indeed we expect they will be. Don't spend a lot of time debating the numbers in the case study. The idea is to give you something concrete to work with, not to give you a review of the lighting market or for you to design a specific product.
- Give your product a name. Make it sell!

Campaign elements	Stakeholders and roles*	How could you use this element for this product?
Buyer Guidance		
a) ENERGY STAR® Criteria		
b) Design/Purchasing Guidance		
Design Competitions		
a) Lighting for Tomorrow (Residential Fixtures)		
b) Commercial Fixtures Competition		
c) Lighting Design Competition for Exterior & Interior Spaces		
d) State-of-the-Art LED Luminaire Showcase		
Technology Demonstrations/Procurements		
a) Demonstrations of Market Readiness		
b) Demonstrations to Test Field Performance		
Commercial Product Testing		
a) Commercial Product Testing Program		
Technical Information		
a) Information Development and Dissemination		
b) Technical Information Network		
Standards and Test Procedures		
a) Standards/Testing Procedure Development Support		
Coordination/Leadership		
a) Facilitating and Coordinating Local and Regional Efforts		
b) Federal Government Leadership		
Other		

* Stakeholders: Standards organizations, manufacturers, industry associations, commercial lighting distributors, residential lighting showrooms, retailers, ESCOs, EEPs, utilities, state energy efficiency programs, large purchasers, energy efficiency advocates, others…

Voices for SSL Efficiency:
Opportunities to Partner and Participate
July 16-17, 2007 ■ Boston, MA

DETAILED CASE STUDY FOR BREAKOUT SESSIONS

Residential-Use Recessed Can Fixture

A core activity of the DOE SSL Market Introduction Workshop will explore case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees will participate in one of the five case study breakout sessions.

This exercise is a vehicle for determining how DOE commercialization plan elements will best support the market introduction needs of new SSL products. It will serve to identify major stakeholders and the elements of the DOE programs where their participation will be most valuable. And it will provide valuable feedback to improve the design of DOE programs.

The Assignment

Each breakout group will consider one case study, working together to:

- Outline a general strategy to sell their target product, identifying issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

The case studies include a lot of questions, provided to help you think about the issues. Some may apply, and some may not. The group doesn't need to address all the questions, but should address the questions and issues that are most important for this case study.

Case Study Structure

Each case study includes:

- An Introduction that identifies the product and places it within its intended market segment, outlining competitive advantages and disadvantages.
- The Product Description offers additional detail on performance.
- Pricing further defines the market served.
- Other Considerations are things the group may want to think about specific to this product.

Please note: The case study products are ***hypothetical*** products with ***plausible*** performance parameters (or that's the intention). In many cases, they would be technically challenging to produce today, but that doesn't matter for this exercise. Don't worry too much about the performance or market numbers, or spend time re-designing the product. This information is provided in the case studies only to help you understand the issues related to this product.

SSL Market Introduction Workshop
Breakout Case Study #3

Residential-Use Recessed Can Fixture

Introduction: The target product is a residential-use recessed can fixture including the lamp and driver electronics. The LED light source, while specifically designed for the fixture, is configured as a replaceable module to enhance serviceability over the life of the installation. This product is intended to compete with incumbent energy-saving alternative, a pin-based compact fluorescent built-in residential light fixture with a 17W source (nominally 1000 lumens). The product placement is such that the LED luminaire offers much better energy efficiency and good economic value when compared to the comparable installed CFL luminaire. An important consideration in marketing will be gaining public recognition and acceptance of the difference between the quoted CFL *system* efficacy, which makes it appear to be better than the offered SSL product, and the *luminaire* efficacy for which the LED comes out ahead. Considering the true energy savings, the life cost of the LED, despite its higher first cost, is competitive with the conventional alternative.

Product Description: Luminaire efficacy of the LED downlight, as an integrated fixture, is 50 LPW for delivered light. This figure is better than four times as efficient as an incandescent or halogen reflector lamp, and approaches five to six times the efficacy of these lamps as installed. It is also significantly more efficient than the pin-based CFL downlight. For the CFL, the published source efficacy is about 60 LPW but the fixture delivers less than that to the work surface. The typical downlight as installed has a luminaire efficacy of about 30 LPW. The life of the lamp portion of the product is *conservatively* expected to be about 16,000 hours, which is better than the CFL or halogen competition in this regard (10,000 hrs.). While further study may show that the LED lifetime is actually longer, questions about the driver electronics and limited operational data at present do not support a claim of longer life. As it is, this translates to somewhat over seven years' life in normal use (4 hrs/day), which makes it very attractive.

Pricing: The price of conventional residential-use recessed can fixtures varies widely depending on type and decorative features, so a range of approximately $60-80 should be assumed, including the light source. Replacement lamp cost for the incumbent technology (CFL) is about $6. Installation of the SSL product is similar to that of the CFL fixture. At $75, the new LED product is priced on the high end of the overall price range, but is well above a comparable design, which would be nearer the low end on price. The higher price is not justified by any special design features, but is thought to be justified by the energy savings and the long life of the product.

Other Considerations: This product competes with conventional replacement light sources (CFL *and* incandescent) for existing installed down-lights, which number in the millions. The LED light offers very substantial operational savings over the incandescent option, and should be an easy sell for that case. In the case of the CFL, the economic argument, while still good, is tighter, but another useful selling feature is that the LED is fully dimmable while the CFL is not. The product as designed requires that the entire LED fixture be installed, as the replacement module is intentionally not compatible with existing fixtures since using the module with a conventional fixture could lead to lower performance, heat transfer problems, and perhaps even a fire hazard. Given this situation, it is likely that the addressable market, at least initially, will be limited to new construction (or remodeling) absent special incentives of some sort. One question to consider would be if such an incentive is warranted, and what would it need to look like. The replacement module is not expected to be widely sold because of the long life of the LEDs, but is

necessary to give consumers a level of comfort with the new technology. Its part cost is about 80% of the entire fixture cost, but replacement is simple and can be done by the homeowner. The replaceable module concept also allows the possibility of an upgrade in the future to accommodate the rapidly advancing performance of the technology. This feature may be a useful selling point and may also make the product more attractive to several existing sales channels.

The Market: On the order of 25 million residential-use recessed can light fixtures are sold in the U.S. each year, mostly for new construction or remodeling. The installed base is much larger, but is not considered an attractive target for the new SSL product because the entire fixture would need to be replaced. Many parties may be involved in the selection of a lighting fixture for residential applications. Depending on the type of home and whether or not it is custom built, any of the following may have a role: owner, architect, builder, decorator or designer, electrical contractor, and even the electrical distributor. In retrofit situations the occupant has a larger role than in new construction, where the builder or electrical contractor may make the decision. Replacement lamps for the incumbent technologies are sold by a host of outlets ranging from wholesale lighting distributors to retail big box stores to the neighborhood grocery. There would not be a substantial general replacement market for the SSL product, although several channels could carry the integrated fixture and replacement modules. A considerable consumer education effort may be required to make this transition.

The Assignment

Your Job: Your assignment is to design a marketing strategy for this product. The market strategy will need to address squarely pricing and performance issues in dealing with a complex combination of decision-makers and some marketplace confusion as to the difference between luminaire and system efficacy. Your company is a new joint venture between a small engineering company and a mid-sized manufacturer of conventional lighting fixtures. This is your first SSL product – in fact it is your first product as a joint venture. DOE has developed a plan that will involve many public organizations such as government agencies, utility companies, state energy efficiency organizations, industry organizations, and others. They have begun important educational, technical support, and standardization activities intended to accelerate market development. Most activities, however, are not directed at any particular market segment or product type. An important aspect of this market development exercise is to determine how you can most effectively use these programs to achieve your goals. How should DOE or the other organizations apply or improve these programs to best support the needs of this target product and market?

The Task, Part I: Frame the general outlines of the marketing strategy.

- Where are the weaknesses in the incumbent products that can provide new opportunity? How can you exploit them? What are the key competitive barriers to success? What are the technological barriers to success?
- How can you best exploit the energy savings inherent in this product to foster market acceptance?
- What has to happen for a successful market introduction of an energy-efficient residential-use recessed can fixture? Define "success." What are your unit sales goals for the first year or two?
- What segments or niches of this residential market might be particularly appropriate for initial attention? Who are the influencers in these segments?
- What buyer behaviors will need to change in order to achieve success? What are the barriers to these changes? How can you address them?
- What are the appropriate sales channels? What sort of activities will you need to engage these outlets for your product?
- What other barriers do you perceive to marketing of this product?

The Task, Part II: Identify the roles of the government and non-government agencies and organizations. What market introduction options could DOE (and its partners) initiate?

- In the table below are listed some potential market-assisting activities that many public and industry organizations may be willing to support. Which do you think would be most useful? How would you apply these activities to your overall plan?
- Which activities are not useful for this particular product? Why? Could they be improved?
- What other elements would you add to this list?
- You have heard about the commercialization activities at the DOE. Which elements of the DOE plan would best contribute to your market plan?
- What other groups will be most important to engage to achieve success? With which aspects of your plan can they most usefully assist?

General Comments and Advice:

- Your team has limited time to put together a solution to this assignment. For best results (and most useful for this workshop) spend only a portion of the first day's breakout session on Part I and do some brainstorming on Part II. Use the second day breakout to complete your evaluation to tidy up your presentation.
- Don't spend a lot of time debating the numbers in the case study. The idea is to give you something concrete to work with, not to give you a review of the lighting market or for you to design a specific product.
- Give your product a name. Make it sell!

Campaign elements	Stakeholders and roles*	How could you use this element for this product?
Buyer Guidance		
a) ENERGY STAR® Criteria		
b) Design/Purchasing Guidance		
Design Competitions		
a) Lighting for Tomorrow (Residential Fixtures)		
b) Commercial Fixtures Competition		
c) Lighting Design Competition for Exterior & Interior Spaces		
d) State-of-the-Art LED Luminaire Showcase		
Technology Demonstrations/Procurements		
a) Demonstrations of Market Readiness		
b) Demonstrations to Test Field Performance		
Commercial Product Testing		
a) Commercial Product Testing Program		
Technical Information		
a) Information Development and Dissemination		
b) Technical Information Network		
Standards and Test Procedures		
a) Standards/Testing Procedure Development Support		
Coordination/Leadership		
a) Facilitating and Coordinating Local and Regional Efforts		
b) Federal Government Leadership		
Other		

* Stakeholders: Standards organizations, manufacturers, industry associations, commercial lighting distributors, residential lighting showrooms, retailers, ESCOs, EEPs, utilities, state energy efficiency programs, large purchasers, energy efficiency advocates, others…

Voices for SSL Efficiency:
Opportunities to Partner and Participate
July 16-17, 2007 ■ Boston, MA

DETAILED CASE STUDY FOR BREAKOUT SESSIONS

LED Outdoor Walkway and Streetscape Light

A core activity of the DOE SSL Market Introduction Workshop will explore case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees will participate in one of the five case study breakout sessions.

This exercise is a vehicle for determining how DOE commercialization plan elements will best support the market introduction needs of new SSL products. It will serve to identify major stakeholders and the elements of the DOE programs where their participation will be most valuable. And it will provide valuable feedback to improve the design of DOE programs.

The Assignment

Each breakout group will consider one case study, working together to:

- Outline a general strategy to sell their target product, identifying issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

The case studies include a lot of questions, provided to help you think about the issues. Some may apply, and some may not. The group doesn't need to address all the questions, but should address the questions and issues that are most important for this case study.

Case Study Structure

Each case study includes:

- An Introduction that identifies the product and places it within its intended market segment, outlining competitive advantages and disadvantages.
- The Product Description offers additional detail on performance.
- Pricing further defines the market served.
- Other Considerations are things the group may want to think about specific to this product.

Please note: The case study products are ***hypothetical*** products with ***plausible*** performance parameters (or that's the intention). In many cases, they would be technically challenging to produce today, but that doesn't matter for this exercise. Don't worry too much about the performance or market numbers, or spend time re-designing the product. This information is provided in the case studies only to help you understand the issues related to this product.

SSL Market Introduction Workshop
Breakout Case Study #4

LED Outdoor Walkway and Streetscape Light

Introduction: Outside area lighting is a difficult challenge for SSL. High Pressure Sodium (HPS) lights are quite energy efficient, have reasonably long lifetimes, and deliver a lot of light. LEDs nonetheless offer two potential advantages in this situation. First, LED source technology today is capable of an efficiency approaching those of HPS and soon will likely surpass it, and the directionality of the LEDs should also allow luminaire efficiency to be higher than for HPS. Second, the LED color quality is much better than HPS. In many applications, this last "advantage" is not terribly important. However, in some areas, particularly historic districts, pedestrian shopping areas, or certain park or residential situations, better color may be a selling point. The target product is positioned as better than the HPS in terms of efficiency, having a longer life, and much better in terms of color quality. The price is somewhat higher than a comparable HPS fixture, but because the fixtures themselves are somewhat expensive in this market, it is not a large factor. The extra energy savings, while not as great as some applications, is nonetheless thought to be important in this application and should appeal to municipalities and utilities.

Product Description: The target product is a full cutoff LED outdoor walkway luminaire for illuminating pedestrian walkways, downtown streetscapes, residential neighborhoods, and public parks. This product is intended to be mounted at heights in the range of 10 to 16 feet. Light output delivered from the fixture is 3200 lumens while consuming 40W (a *luminaire* efficacy, including the LED driver, of 80 LPW). A 50W HPS *lamp* generates about 3600 lumens at an efficacy of 72 LPW. But the fixture efficiency for a full cutoff design is about 80%, so the luminaire delivers only about 2880 lumens resulting in a luminaire efficacy about 58 LPW. The directional nature of the LED sources makes them particularly attractive sources when dark-sky or other light-pollution considerations are important because it provides some "built-in" cutoff characteristics, simplifying fixture design. Additionally, with a color rendition index (CRI) of 80 easily achievable, the quality of the LED light exceeds HPS lamps, which typically have a pronounced yellowish color leading to a nominal CRI of approximately 21. This feature should make the product particularly attractive for historic areas or downtown areas where improved light quality will be appreciated. While halogen lamps are sometimes used in installations when color is important, their efficacy is extremely poor. The LED product offers a compromise of "good" color rendition while maintaining high energy efficiency. The design target for lifetime for the LED source modules is 50,000 operating hours, which is over twice that for the best competing conventional lamps, even with anticipated improvements. For an application such as this one, the lights may be on for many hours of the day, year round, so this amounts to about a 10-year life. The driver, on the other hand, is an electronic device subject to temperature extremes and harsh weather, and may have a highly variable life of 5-10 years. To avoid any possible sales resistance because of either driver problems or skepticism on the part of municipal buyers, both the light source and the driver can be separately replaced with design-specific modules, although this is expected to be a rare occurrence. This feature, however, also allows for upgrades as the SSL product technology advances which are quite likely to occur over the 10-20 year life of the installation. The luminaire cannot be retro-fitted with a conventional light source, assuring that neither energy savings nor dark-sky advantages can be compromised.

Pricing: The LED street light is priced at $1800, complete. Comparable products using conventional technology sell in the range of $1200-$1600 wholesale, including a halogen or sodium lamp. (Higher prices may apply for more intricate or decorative designs.) The manufacturer expects that the energy savings and long lifetime, especially, but also the better color quality and the attractive design all combine to fully justify this cost premium. The differential cost between the LED lamps and conventional lamps is higher, but is a fairly small fraction of the total. The driver is an important additional cost factor for the manufacturer, as it uses high-reliability technology for harsh outdoor environments.

The Market: Outdoor lighting consumes about 12% of the total lighting energy consumption in the U.S. It is also very public, so success in entering this market not only offers significant energy savings but also some educational aspects that may help promote solid-state lighting for other applications. This makes it an attractive target for the efforts of utilities, municipalities, and energy-efficiency organizations. The market strategy should take full advantage of these opportunities. However, this is not a high-volume market. Annual sales number in the thousands rather than the millions, as do some other segments. At the same time, the higher prices combine to make it a reasonably attractive market from the point of view of dollar sales volume. Also, as the installations have a long lifetime, there is, in this case a more significant potential for the module replacement market than may apply to other segments served by SSL.

Other Considerations: Several issues relating to the introduction of new technology provide market barriers to entry. These will need to be addressed in any marketing strategy for this product.

1. Maintenance. This is potentially a very important advantage because of the longer life. The manufacturer has addressed this issue from a practical perspective with the replaceable driver and source modules, but buyers may want some assurance of continued availability.
2. Lumen output. Although the fixture provides significantly *higher* delivered light to the walkway surface and surrounding area because no upward-directed light is generated by the LEDs, buyers may perceive this as a low-luminance fixture because of the advertised lumen output of the competing HPS *lamps*. What kind of educational efforts might help this situation? Is this an area that governments, energy efficiency organizations or utilities should emphasize, and if so what is the best way?
3. Color quality. This product is significantly better than HPS technology in this regard, but falls somewhat short as compared to a halogen alternative on CRI. So there is a compromise between color quality and operating cost. How can this best be sold? Educational efforts? Public demonstrations?

Assignment

Your Job: Your assignment is to design a marketing strategy for this product. Your company, a specialty manufacturer of outdoor lighting fixtures, has many years of experience with traditional lighting and many relationships along the value chain, but this is your first SSL product. Fortunately you are addressing a highly motivated market. Environmental factors have had some influence in this market for some time. Many municipalities are embarking on serious energy savings programs, and saving money for maintenance has always been an important consideration. DOE has developed a plan that will involve many public organizations such as government agencies, utility companies, state energy efficiency organizations, industry organizations, and others. They have begun important educational, technical support, and standardization activities intended to accelerate market development. Most of these activities, however, are not directed at any particular market segment or product type. The main purpose of this part of your market development process is to determine how you can most effectively use

these programs to achieve your goals. What changes, if any, might improve these programs to better support the needs of your product and market?

The Task, Part I: Frame the general outlines of the marketing strategy.

- Where are the weaknesses in the incumbent products that can provide new opportunity? How can you exploit them? What are the key competitive barriers to success? What are the technological barriers to success?
- How can you best exploit the energy savings inherent in this product to foster market acceptance? Address some of the particular issues outlined for street lighting above.
- What has to happen for a successful market introduction of an LED outdoor area? What might be some useful unit sales goals for the first year or two? (We don't have a lot of specific market data. Either invent numbers for the total addressable market or compare as a percentage.)
- Maintenance cost savings drove the acceptance of LED stoplights in the U.S. There are, however, issues of availability of replacement parts for a new technology. An open standardized interface for the modules would ensure that multiple suppliers could provide compatible replacement products and help to alleviate this barrier. How could this be expedited?
- What behaviors will need to change in order to achieve success? What sort of educational efforts or demonstrations might help to show the advantages for this technology in these applications?

The Task, Part II: Identify the roles of the government and non-government agencies and organizations.

- In the table below are listed some potential market-assisting activities that many public and industry organizations may be willing to support. Which do you think would be most useful? How would you apply these activities to your overall plan?
- Which activities are not useful for this particular product? Why? Could they be improved?
- What other elements would you add to this list?
- You have heard about the commercialization activities at the DOE. What aspects of the DOE program will be most useful for this application and market?
- What other groups will be most important to engage to achieve success?

General Comments and Advice:

- Your team has limited time to put together a solution to this assignment. For best results (and most useful for this workshop) spend only a portion of the first day's breakout session on Part I and do some brainstorming on Part II. Use the second day breakout to complete your evaluation to tidy up your presentation.
- Don't spend a lot of time debating the numbers in the case study. The idea is to give you something concrete to work with, not to give you a review of the lighting market or for you to design a specific product.
- Give your product a name. Make it sell!

Campaign elements	Stakeholders and roles*	How could you use this element for this product?
Buyer Guidance		
a) ENERGY STAR® Criteria		
b) Design/Purchasing Guidance		
Design Competitions		
a) Lighting for Tomorrow (Residential Fixtures)		
b) Commercial Fixtures Competition		
c) Lighting Design Competition for Exterior & Interior Spaces		
d) State-of-the-Art LED Luminaire Showcase		
Technology Demonstrations/Procurements		
a) Demonstrations of Market Readiness		
b) Demonstrations to Test Field Performance		
Commercial Product Testing		
a) Commercial Product Testing Program		
Technical Information		
a) Information Development and Dissemination		
b) Technical Information Network		
Standards and Test Procedures		
a) Standards/Testing Procedure Development Support		
Coordination/Leadership		
a) Facilitating and Coordinating Local and Regional Efforts		
b) Federal Government Leadership		
Other		

* Stakeholders: Standards organizations, manufacturers, industry associations, commercial lighting distributors, residential lighting showrooms, retailers, ESCOs, EEPs, utilities, state energy efficiency programs, large purchasers, energy efficiency advocates, others…

Voices for SSL Efficiency:
Opportunities to Partner and Participate
July 16-17, 2007 ■ Boston, MA

DETAILED CASE STUDY FOR BREAKOUT SESSIONS

LED Spotlight for Retail Store Lighting

A core activity of the DOE SSL Market Introduction Workshop will explore case studies based on five hypothetical SSL products intended for various market applications. Workshop attendees will participate in one of the five case study breakout sessions.

This exercise is a vehicle for determining how DOE commercialization plan elements will best support the market introduction needs of new SSL products. It will serve to identify major stakeholders and the elements of the DOE programs where their participation will be most valuable. And it will provide valuable feedback to improve the design of DOE programs.

The Assignment

Each breakout group will consider one case study, working together to:

- Outline a general strategy to sell their target product, identifying issues that are particularly important for that product, such as barriers to overcome, critical information needs, involvement of critical trade allies, etc.
- Consider which elements of the DOE commercialization programs can best support their strategy and how. Could there be improvements?

The case studies include a lot of questions, provided to help you think about the issues. Some may apply, and some may not. The group doesn't need to address all the questions, but should address the questions and issues that are most important for this case study.

Case Study Structure

Each case study includes:

- An Introduction that identifies the product and places it within its intended market segment, outlining competitive advantages and disadvantages.
- The Product Description offers additional detail on performance.
- Pricing further defines the market served.
- Other Considerations are things the group may want to think about specific to this product.

Please note: The case study products are ***hypothetical*** products with ***plausible*** performance parameters (or that's the intention). In many cases, they would be technically challenging to produce today, but that doesn't matter for this exercise. Don't worry too much about the performance or market numbers, or spend time re-designing the product. This information is provided in the case studies only to help you understand the issues related to this product.

SSL Market Introduction Workshop
Breakout Case Study #5

LED Spotlight for Retail Store Lighting

Introduction: The product offered for this business case is an adjustable LED spotlight intended for accent lighting in retail applications. A typical competing conventional product would be a 50W halogen MR16. The LED has a substantial advantage in terms of energy efficiency – a factor of two – and it lasts over ten times as long as the halogen. The cost of the product is higher than the conventional technology, but the energy savings will make up the first cost difference in only a year or so. Color quality is paramount in these situations, and the halogen light has a slight edge over the LED solution in terms of nominal color rendition, so this is a trade-off. However, there are issues with the measurement of color rendition for LEDs, and the perception is that the difference in color quality is smaller than indicated by the CRI figure, but it nonetheless is a marketing issue to be considered. On the other hand, a potential advantage for the target product is that many potential buyers will highly value the absence of IR radiation from the LED spotlight because it allows their employees to work much more comfortably under the lights, and because certain heat sensitive products, like chocolates, could be put under spotlights.

Product Description: The LED spotlight fixture delivers approximately 1000 lumens, which is comparable to or a little better than an MR16 luminaire of similar design. However, the lamp and driver draw only 25W, providing an efficacy of 40 LPW, twice that of the competing product. Note that this is an integrated design, *not* a "replacement bulb", and in fact the driver module is located remotely from the light source to avoid overheating issues that very likely would result by incorporating it into the "front end" source. The housing, which in combination with the source module provides for heat-sinking of the LEDs in addition to the drive electronics, is not compatible with conventional technology light sources. And, in fact, the light source itself is somewhat larger and differently shaped than an MR16 package for heat control reasons. Lifetime of the LED product is stated to be 40,000 hours – over ten times that of the halogen. For this product, a CRI of 90 has been achieved with a combination of white PC LEDs and multiple additional monochromatic chips. Although nominally not as high a CRI as halogen lighting, the actual color appearance of this product is said to be equally as good. The manufacturer claims that the standard CRI measurement does not adequately express the very high quality of the light and is very concerned that unless the standard is changed customers will never even *see* the light to appreciate how good it is. The color temperature of 3200K, moderately warm, is favored by designers for high-end retail applications, but it is somewhat cooler than the halogen, which could be a disadvantage in some cases. The light would normally be used in combination with fluorescent general ambient lighting. The light is configured such that once the housing is installed, separate LED driver and source modules allow for maintenance or replacement with an upgrade if needed, although this is expected to be a rare occasion. The reason for offering the capability is in part a PR move to overcome possible resistance to a relatively expensive fixture that could not be maintained.

Pricing: The luminaire, including the LED source, driver, adjustable fixture, and housing is priced at $110. Competing high-end designer fixtures may be in the range of $80. While relatively high-priced, the long life, with consequent reduced maintenance cost, and energy savings, justifies the extra cost.

Other Considerations: Commercial lighting purchasers are increasingly sensitive to energy savings and will take that into account when considering the economics. This product is intended specifically to address this market trend. Nevertheless, a one- or two-year payback is about the most they will tolerate in this type of application, primarily because the life of the installation is not necessarily much longer than that. Buyers in these situations are also skeptical of new technology and are particularly concerned with the possibility that replacement parts may not be available when they are needed. Also, for the targeted market segment, lighting designers play a big role in buying decisions. The appearance and quality of light are paramount while pricing is a secondary but nonetheless important consideration.

The Market: The design and pricing of this light definitely place it in the high-end retail market segment, including boutiques, jewelry stores, etc., which is a relatively small fraction – perhaps 10% in terms of unit sales – of the total retail applications market. The manufacturer contemplates future designs – perhaps in a year or two – that will address additional segments, including, say grocery stores or restaurants and other medium-sized enterprises. However, at the moment the cost to make the fixture may be too high to offer a competitive product in those segments. Operational costs are important also, particularly in a mall setting where many of these stores are located. In these cases the owner of the property may also have something to say about the choice of product. In either case it is not an easy sell for new LED technology. The appearance of merchandise under existing lighting solutions is well known. Designers are risking their reputations by suggesting a new approach and may be reluctant to do so. Retail lighting (including ambient general lighting) accounts for about 20% of the total commercial indoor lighting energy consumption in the United States making it the biggest segment in terms of energy consumption. Typical of most commercial installations, lights are operated for a relatively large part of the day – amounting to about 80 to 100 or more hours/week. And hardwired incandescent lighting fixtures constitute about 20% of the total commercial lighting market but most of these are recessed can lights. As far as the current industry and supply chain structure, replacement lamps are a big business: miniature incandescent lamps, the incumbent competition for the target product, account for over a quarter of total lamp shipments (consumer and commercial) in the U.S. – over one billion/year and cost on the order of $8 apiece.

The Assignment

Your Job: Your assignment is to design a marketing strategy for this product. Trade-offs in price, energy savings, and color quality will need to be addressed in a constructive way. The marketing strategy will need to address quality and pricing issues squarely in dealing with a complex combination of decision-makers. Your company is a mid-sized manufacturer of commercial lighting fixtures and has been in business for over 25 years selling conventional lighting products and a few early LED products. You have had some success in the market targeted for this product. DOE has developed a plan that will involve many public organizations such as government agencies, utility companies, state energy efficiency organizations, industry organizations, and others. They have begun important educational, technical support, and standardization activities intended to accelerate market development. Most activities, however, are not directed at any particular market segment or product type. An important aspect of this market development exercise is to determine how you can most effectively use these programs to achieve your goals. How should DOE or the other organizations apply or improve these programs to best support the needs of this target product and market?

The Task, Part I: Frame the general outlines of the marketing strategy.

- Is this a good opportunity? Why or why not? Where are the weaknesses in the incumbent products that can provide new opportunity? How can you exploit them? What are the key competitive barriers to success? What are the technological barriers to success?
- How can you best exploit the energy savings inherent in this product to foster market acceptance?
- What has to happen for a successful market introduction of an energy-efficient LED spotlight in this segment? Define "success." What are your unit sales goals for the first year or two?
- What other segments of the commercial or industrial marketplace might be appropriate for this product? What market actions or product changes would make it more useful in or acceptable to these other segments?
- Decision-makers and buyers have to consider many factors and may be risk-averse (although some may be technology advocates, too). What behaviors will need to change in order to achieve success? What are the barriers to these changes? How can you address them? How can government testing or educational programs assist you?
- What sort of issues do you expect to encounter with your distributors? How will you deal with your traditional sales partners that may lose replacement business in the new paradigm?
- Have the designers appropriately addressed the "maintenance issue" for the new technology? Is it important to the marketing of this product?
- What other barriers do you perceive to marketing of this product?

The Task, Part II: Identify the roles of the government and non-government agencies and organizations.

- In the table below are listed some potential market-assisting activities that many public and industry organizations may be willing to support. Which do you think would be most useful? How might some of these help to address the CRI issue mentioned above? How would you apply these activities to your overall plan?
- Which activities are not useful for this particular product? Why? Could they be improved?
- What other elements would you add to this list?
- You have heard about the commercialization activities at the Department of Energy. How can the DOE best make a contribution to your market plan?
- What other groups will be most important to engage to achieve success? With which aspects of your plan can they most usefully assist?

General Comments and Advice:

- Your team has limited time to put together a solution to this assignment. For best results (and most useful for this workshop) spend only a portion of the first day's breakout session on Part I and do some brainstorming on Part II. Use the second day breakout to complete your evaluation to tidy up your presentation.
- Don't spend a lot of time debating the numbers in the case study. The idea is to give you something concrete to work with, not to give you a review of the lighting market or for you to design a specific product.
- Give your product a name. Make it sell!

Campaign elements	Stakeholders and roles*	How could you use this element for this product?
Buyer Guidance		
a) ENERGY STAR® Criteria		
b) Design/Purchasing Guidance		
Design Competitions		
a) Lighting for Tomorrow (Residential Fixtures)		
b) Commercial Fixtures Competition		
c) Lighting Design Competition for Exterior & Interior Spaces		
d) State-of-the-Art LED Luminaire Showcase		
Technology Demonstrations/Procurements		
a) Demonstrations of Market Readiness		
b) Demonstrations to Test Field Performance		
Commercial Product Testing		
a) Commercial Product Testing Program		
Technical Information		
a) Information Development and Dissemination		
b) Technical Information Network		
Standards and Test Procedures		
a) Standards/Testing Procedure Development Support		
Coordination/Leadership		
a) Facilitating and Coordinating Local and Regional Efforts		
b) Federal Government Leadership		
Other		

* Stakeholders: Standards organizations, manufacturers, industry associations, commercial lighting distributors, residential lighting showrooms, retailers, ESCOs, EEPs, utilities, state energy efficiency programs, large purchasers, energy efficiency advocates, others…

APPENDIX E: Index of Acronyms

A/C	Alternating current
ALA	American Lighting Association
ANSI	American National Standards Institute
ANSLG	American National Standard Lighting Group
CCT	Correlated Color Temperature
CEC	California Energy Commission
CEE	Consortium for Energy Efficiency
CFL	Compact Fluorescent Lighting
CIE	International Commission on Illumination
CRI	Color Rendering Index
CSA	Canadian Standards Association
DOE	U.S. Department of Energy
EEP	Energy Efficiency Partnership
EERE	U.S. DOE Office of Energy Efficiency and Renewable Energy
GSA	General Services Administration
HPS	High Pressure Sodium
HVAC	Heating, Ventilation, and Air Conditioning
IALD	International Association of Lighting Designers
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IES	Industrial Electronics Society
IESNA	Illuminating Engineering Society of North America
IR/UV	Infrared/Ultraviolet (radiation)
kWh	Kilowatt hours
LED	Light Emitting Diodes
LFT	Lighting for Tomorrow
lm/W	Lumens per watt
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MR	Multifaceted reflector
NEEA	Northwest Energy Efficiency Alliance
NEEP	Northeast Energy Efficiency Partnerships
NEMA	National Electrical Manufacturers Association
NETL	National Energy Technology Laboratory
NGLIA	Next Generation Lighting Industry Alliance
NIST	National Institute of Standards and Technology

OLED	Organic Light Emitting Diode
PDA	Personal Digital Assistant
PNNL	Pacific Northwest National Laboratory
PR	Public Relations
PSA	Public Service Announcement
ROI	Return on investment
RP	Recommended practice
SCE	Southern California Edison
SPIE	International Society for Optical Engineering
SSL	Solid-State Lighting
SWOT	Strengths, Weakness, Opportunities, and Threats
UL	Underwriters Laboratories
USDC	U.S. Display Corporation
UV	Ultraviolet light
VHS	Video Home System
W	Watt