U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE SSL R&D Workshop Mission

DOE SSL R&D Workshop
Long Beach, CA
January 31 – February 2, 2017

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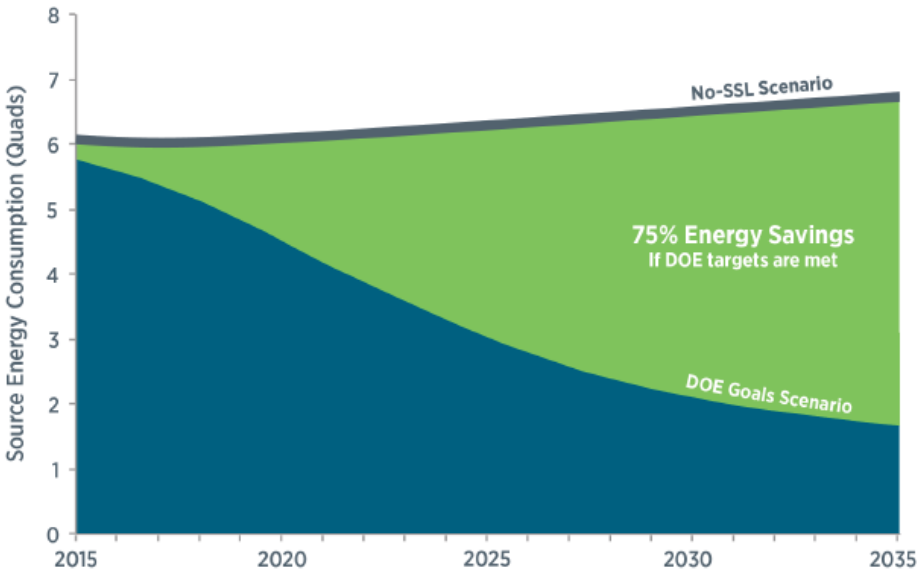
Where are we going and how do we get there?

SSL Energy Savings Projection



Where are we at?

Program level milestones:

Table 7.3 LED Package and Luminaire Milestones

Year	Milestones
FY10	Package: >140 lm/W (cool white); >90 lm/W (warm white); <$13/klm (cool white)
FY12	Luminaire: 100 lm/W; ~1,000 lm; 3500K; 80 CRI; 50,000 hours
FY15	Package: ~$1/klm (cool white); ~$1.1/klm (warm white)
FY17	Luminaire: >3,500 lm (neutral white); <$100; >150 lm/W
FY20	Luminaire: 200 lm/W Connected troffer with integrated controls: <$85
FY25	Full-color tunable luminaire: 200 lm/W (@ 3000K, CRI = 90), >3,500 lm

Note: Packaged devices measured at 25°C and 1 W/mm^2. Prices are for 1000-off quantities

Table 7.4 OLED Panel and Luminaire Milestones

Year	Milestones
FY10	Panel: >60 lm/W
FY12	Laboratory Panel: 200 lm/panel; >70 lm/W; >10,000 hours
FY15	Commercial Panel: <$200/klm (price); >80 lm/W; 40,000 hours; CRI>90
FY17	Commercial Panel: 100 lm/W; CRI >90; L_{70} 50,000 hours
FY20	Luminaire: 100 lm/W; $50/klm
FY25	Commercial Panel: 160 lm/W

Example topic milestones:

C.1.2 Stable White Devices

Description: Develop novel materials and structures that can help create a highly efficient, stable white device. The device should have good color, long lifetime, and high efficiency, even at high brightness. The approach may include the development of highly efficient blue emitter materials and hosts or may comprise a device architecture leading to longer lifetime. Any proposed solutions should keep cost, complexity, and feasibility of scale-up in mind. Materials/structures should be demonstrated in OLED devices that are characterized to ascertain the performance as compared to the metrics below. Novel materials/structures should demonstrate high stability, while maintaining or improving other metrics.

Metrics	2014 Status	2020 Target
Lumen maintenance (L_{70}) from 10,000 lm/m^2	40,000	>50,000 hrs
Efficacy without extraction enhancement (lm/W)	35 lm/W	50 lm/W
CRI	90	>90

A.1.3 Down-Converters

Description: Explore new, high-efficiency wavelength conversion materials for the purposes of creating warm-white LEDs, with a particular emphasis on improving spectral efficiency with high color quality and improved thermal stability and longevity. Non-rare earth metal and nontoxic down-converters are encouraged.

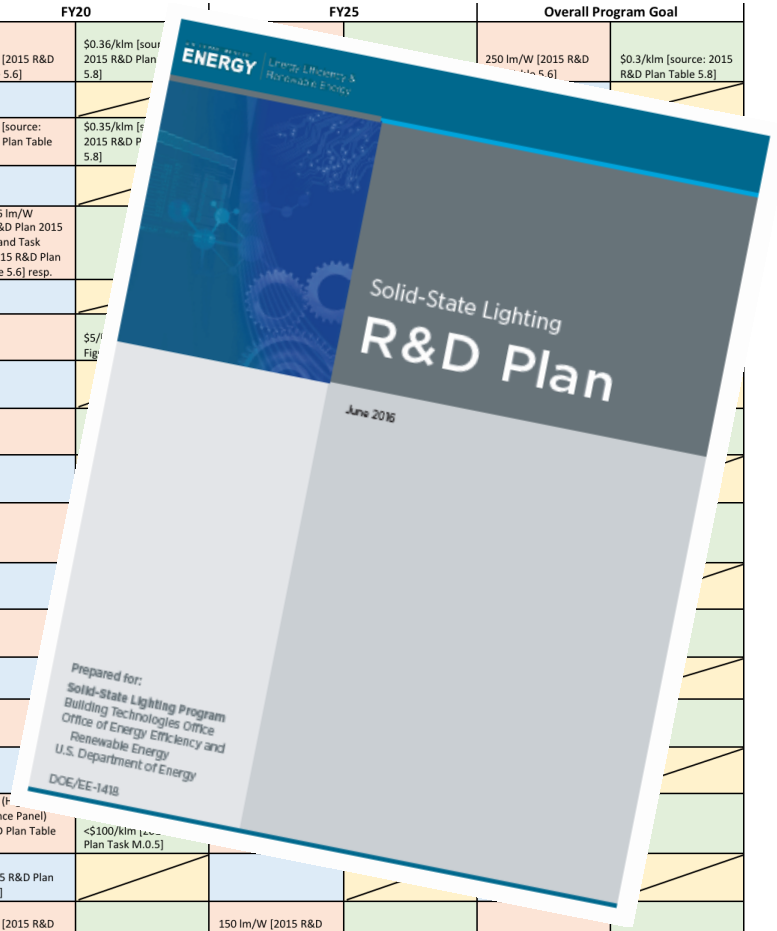
Metrics	2014 Status	2020 Targets
Quantum yield (25°C) across the visible spectrum	95% (Green) 90% (Red)	99% (Green) 95% (Red)
Thermal stability – Relative quantum yield at 150°C vs. 25°C	90%	95%
Spectral FWHM	100 nm (Red/Green)	30 nm (Red) 70 nm (Green)
Color shift over time (when integrated into pc-LED)	Δu'v' <0.007 at 6,000 hours	Δu'v' <0.002 over life
Flux density saturation – Relative quantum yield (QY) at 1 W/mm^2 (optical flux) vs. peak QY	-	95%

Are milestones and targets correct, up to date, and consistent?

R&D Goals

Goals from 2016 R&D Plan

		2014 (Actual)		FY15		FY17		FY20		FY25		Overall Program Goal	
LED	Warm-White Package**	146 lm/W [2015 R&D Plan Table 5.6]	$1.7/klm [source: 2015 R&D Plan Table 5.8]	162 lm/W [2015 R&D Plan Table 5.6]	$1.2/klm or ~$1.1/klm [source: 2015 R&D Plan Table 5.8 and Table 7.3 resp.]	190 lm/W [source: 2015 R&D Plan Table 5.8]	$0.7/klm [source: 2015 R&D Plan Table 5.8]	220 lm/W [2015 R&D Plan Table 5.6]	$0.36/klm [sour 2015 R&D Plan 5.8]			250 lm/W [2015 R&D	$0.3/klm [source: 2015 R&D Plan Table 5.8]
				50K [2015 R&D Plan Section 7.2.2]									
	Cool-White Package**	173 lm/W [2015 R&D Plan Table 5.6]	$1.4/klm [source: 2015 R&D Plan Table 5.8]	185 lm/W [2015 R&D Plan Table 5.6]	$1/klm [source: 2015 R&D Plan Table 7.3 and Table 5.8]	205 lm/W [source: 2015 R&D Plan Table 5.8]	$0.6/klm [source: 2015 R&D Plan Table 5.8]	226 lm/W [source: 2015 R&D Plan Table 5.8]	$0.35/klm [s 2015 R&D P 5.8]				
				50K [2015 R&D Plan Section 7.2.2]									
	Luminaire	120, 110, or 108 lm/W [2015 R&D Plan Section 7.2.2], [2015 R&D Plan Task B.3.6] [R&D Plan Table 5.6] resp.		125 lm/W [2015 R&D Plan Table 5.6]		>150 lm/W [Source R&D Plan 2015 Table 7.3]	<$100 [Source R&D Plan 2015 Table 7.3]	200 or 196 lm/W [Source R&D Plan 2015 Table 7.3 and Task B.3.6], [2015 R&D Plan 2015 Table 5.6] resp.					
	Omnidirectional Lamp*	78 lm/W [R&D Plan Table 2.1]	$11/klm [R&D Plan Table 2.1]		$10/klm [R&D Plan Figure 5.18]		$6.9/klm [R&D Plan Figure 5.18]		$5/ Fig				
		25K [R&D Plan Table 2.1]											
	Downlight	60 lm/W [R&D Plan Table 2.1]	$30/klm or $20 [2015 R&D Plan Table 2.1 and Task B.6.4 resp.]										
		36K [R&D Plan Table 2.1]											
	Linear Troffer*	93 lm/W [R&D Plan Table 2.1]	$31/klm [R&D Plan Table 2.1]										
		56K [R&D Plan Table 2.1]											
	Low/High Bay*	90 lm/W [R&D Plan Table 2.1]	$38/klm [R&D Plan Table 2.1]										
		75K [R&D Plan Table 2.1]											
	Streetlight*	93 lm/W [R&D Plan Table 2.1]	$50/klm or $200 [2015 R&D Plan Table 2.1 and Task B.6.4 resp.]										
		55K [R&D Plan Table 2.1]											
OLED	Panel	60 lm/W [R&D Plan Figure 6.4 and text above]		>80 lm/W (Commercial Panel) [2015 R&D Plan Table 7.4]	<$200/klm (price for Commercial Panel) [2015 R&D Plan Table 7.4]		$100/klm (Commercial Panel) [2015 R&D Plan Table 7.4]	150 lm/W (H Performance Panel) [2015 R&D Plan Table 7.4]	<$100/klm [2 Plan Task M.0.5]				
		40K [2015 R&D Plan Task C.1.2]		40K hrs (Commercial Panel) [2015 R&D Plan Table 7.4]				>50K [2015 R&D Plan Task C.1.2]					
	Luminaire (normalized by panel #?)	46 or 51 lm/W [2015 R&D Plan Table 2.1 or Task D.4.2 resp.]	$870/klm [R&D Plan Table 2.1]			100 lm/W [2015 R&D Plan Table 7.4]		125 lm/W [2015 R&D Plan Task D.4.2]		150 lm/W [2015 R&D Plan Table 7.4]			
		40k OR 15K [2015 R&D Plan Table 2.1 AND Task D.4.2 resp.]						50K [2015 R&D Plan Task D.4.2]					



We also need more specificity for targets for certain luminaire types, lighting applications

How do we get there? What R&D is necessary?

Workshop Inputs-

- Presentations
- Posters
- Panel discussions
- Comment Cards
- Comments/Questions/Discussions
- **Group Discussion and Feedback – Topic Tables**

2017 R&D WORKSHOP COMMENT CARD

Check the appropriate box to indicate what your comment relates to. One comment per card, please!

- ☐ A specific topic/task (which?) _____
- ☐ One of the "Questions to Consider" Topic Area: _____ Question #: _____
- ☐ What you'd like to see in the new R&D Plan
- ☐ Program Milestones ☐ Other
- ☐ Bonus Question: If you had $1M for R&D, what topic would you support?

Remarks: *Name (optional):* _____

Please return completed cards to the Registration Desk at any time during the workshop.
(Extra cards also available there.)

Group Discussion and Feedback – Topic Tables

Topic Tables to discuss R&D priorities

1. Instructions and questions for anticipated OLED/LED topics in folders
2. Pick a topic, meet your table-mates, have a discussion, answer the questions
3. Provide additional inputs not prompted by questions

R&D Topics

LED

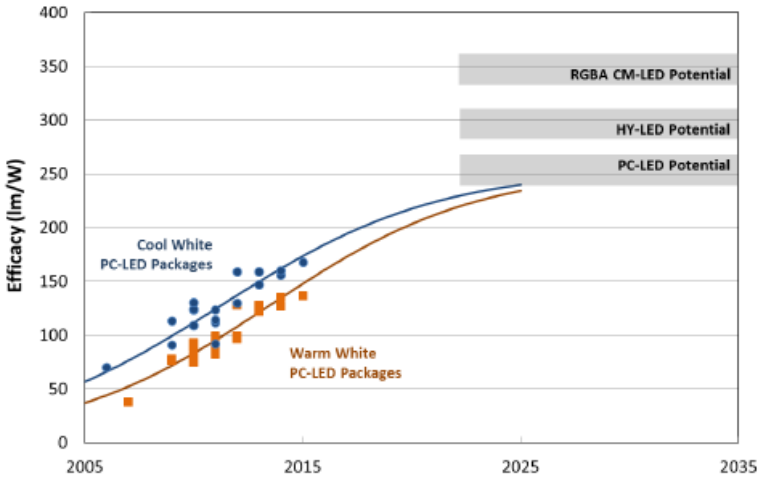
1. Emitter Materials
2. Down-Converters
3. LED Package and Encapsulation
4. Novel Device Architectures
5. LED Drivers
6. Novel Luminaires
7. Reliability and Color Stability
8. Connected Lighting and Controls
9. Human Physiological Responses to Light
10. What else …?

OLED

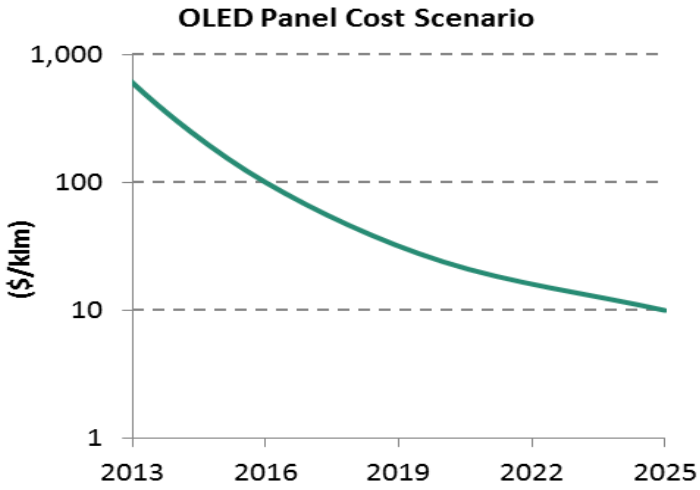
1. Organic Stack (emitters, transport materials, charge generation layers, …)
2. Supporting Structures (substrates, encapsulants, electrodes, light extraction, …)
3. Equipment, panel integration, and manufacturing
4. Luminaire design and integration & application/market development
5. What else …?

Particular Challenges

LED Efficacy



OLED Cost



Luminaire Integration
Luminaire manufacturing

OLED Panel Integration

Application understanding
Utilization efficiency
Physiological Responses

DOE SSL Program Input Strategy

LED 9/14-15/2016
OLED 10/18-10/2016

You Are Here

Other Guidance for 2017-

- Animal Responses to Light Roundtable (4/19/2016)
- Connected Lighting Workshop (6/8-9/2016)
- Human Physiological Responses to Light Roundtable (7/19/2016)
- Horticultural Lighting Experts (ongoing)
- National Academy of Science Program Review (coming soon)