

R&D Program Update

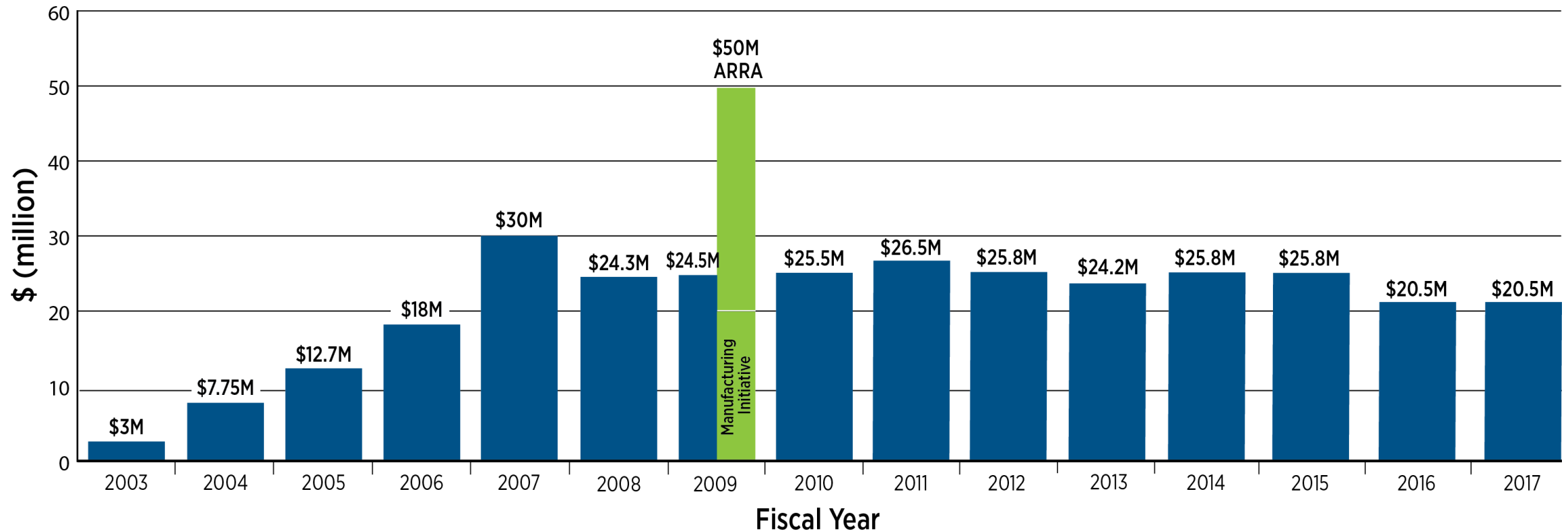
2017 DOE SSL R&D Workshop

February 1, 2017

James R. Brodrick, Ph.D.

Lighting Program Manager
U.S. Department of Energy

Congressional Appropriations



Almost **270** R&D projects
funded to date have
resulted in more than
270 patents

2

BUILDING TECHNOLOGIES OFFICE

BUILDING

Primary Research Organization	Titles of Patent Applications (nonprovisional patents granted shown in bold)	
	<ul style="list-style-type: none"> • Expandable LED Array Interconnects¹ • LED Package Element with Internal Manifold for Bubble-Free Ink Placement² • LED Structure with Enhanced Mirror Reflectivity³ • Light Emitting Diode with Inkjet Roughness for Link⁴ 	<ul style="list-style-type: none"> • Ultra-Thin Organic Contacts for P-N Junction Light Emitting Devices⁵ • High Power LED Array

SOLID-STATE LIGHTING

Solid-State Lighting Patents Resulting from DOE-Funded Projects

As of January 2017, 118 solid-state lighting (SSL) patents have been awarded to research projects funded by the U.S. Department of Energy. Since December 2000, when DOE began funding SSL research projects, a total of 274 patent applications have been submitted, ranging from large businesses (89) and small businesses (99) to universities (74) and national laboratories (12).

DOE tracks three types of patent applications. A brief overview and the symbol used to identify each application type follows:

- NP U.S. Nonprovisional Patents** – the standard U.S. patent application. Nonprovisional applications are examined by a patent examiner and may be issued as a patent if all requirements for patentability are met.
- P U.S. Provisional Patents** – a lower-cost patent application filing option in the U.S. used to establish an early effective filing date in a later-filed nonprovisional patent application. An applicant who files a provisional application must file a corresponding nonprovisional application for patent during the 12-month pendency period in order to benefit.
- PCT International Patents** – an international patent application under the Patent Cooperation Treaty (PCT), by which applicants can simultaneously seek protection for intellectual property in 148 countries, including the U.S.¹

Each patent application has a unique application number used to track progress until a patent is awarded. Patent applications may not be unique, and often we see the same title for multiple patent applications. For this reason, duplicate titles may be listed in the table below, but each instance corresponds to a unique patent application. Provisional patents are only tracked until the nonprovisional patent is filed, at which point they are superseded to avoid double counting. If a nonprovisional U.S. patent and an international patent are linked (i.e., one is a continuation of the other), the title is listed once but designated with both ^{NP} and ^{PCT}. In instances where the patent information is protected, the patent may be listed by application type, but no title is provided.

Primary Research Organization	Titles of Patent Applications (nonprovisional patents granted shown in bold)	
	<ul style="list-style-type: none"> • ^{NP} U.S. Nonprovisional • ^P U.S. Provisional • ^{PCT} International 	<ul style="list-style-type: none"> • One provisional patent application filed
Aquiltron	<ul style="list-style-type: none"> • Optoelectronic Device with Nanoparticle Embedded Layer^{NP} • Methods for Improved Growth of Group III Nitride Buffer Injection/Passivation Layer^{NP} 	<ul style="list-style-type: none"> • Methods for Improved Growth of Group III Nitride Buffer Injection/Passivation Layer^{NP} • Multiple Complementary Gas Distribution Assemblies^{NP}
Applied Materials, Inc.	<ul style="list-style-type: none"> • Method and Apparatus for Inducing Turbulent Flow of a Processing Chamber Cleaning Gas^{NP} • Method and Apparatus for Inducing Turbulent Flow of a Processing Chamber Cleaning Gas^{NP} 	<ul style="list-style-type: none"> • Metal Compounds and Methods and their use in a processing chamber^{NP} • Three dimensional pattern applications filed^{NP}
Arizona State University	<ul style="list-style-type: none"> • Iridium Complexes Demonstrating Broadband Emission Through Controlled Geometric Distortion and Applications^{NP} • Iridium Complexes Demonstrating Broadband Emission Through Controlled Geometric Distortion and Applications^{NP} 	<ul style="list-style-type: none"> • OLED Substrate Consisting of Transparent Conductive Oxide (TCO) and Anti-Reflection Undercoat^{NP} • Optical Devices Featuring Textured Semiconductor Layer^{NP}
Arkema, Inc.	<ul style="list-style-type: none"> • Chemical Vapor Deposition Using N.O. Polyolate Ligand Complexes of Metals^{NP} • Optical Devices Featuring Textured Semiconductor Layers^{NP} 	<ul style="list-style-type: none"> • Optical Devices Featuring Textured Semiconductor Layers^{NP}
Boston University	<ul style="list-style-type: none"> • Optical Devices Featuring Textured Semiconductor Layers^{NP} • Optical Devices Featuring Textured Semiconductor Layers^{NP} 	<ul style="list-style-type: none"> • Optical Devices Featuring Textured Semiconductor Layers^{NP}

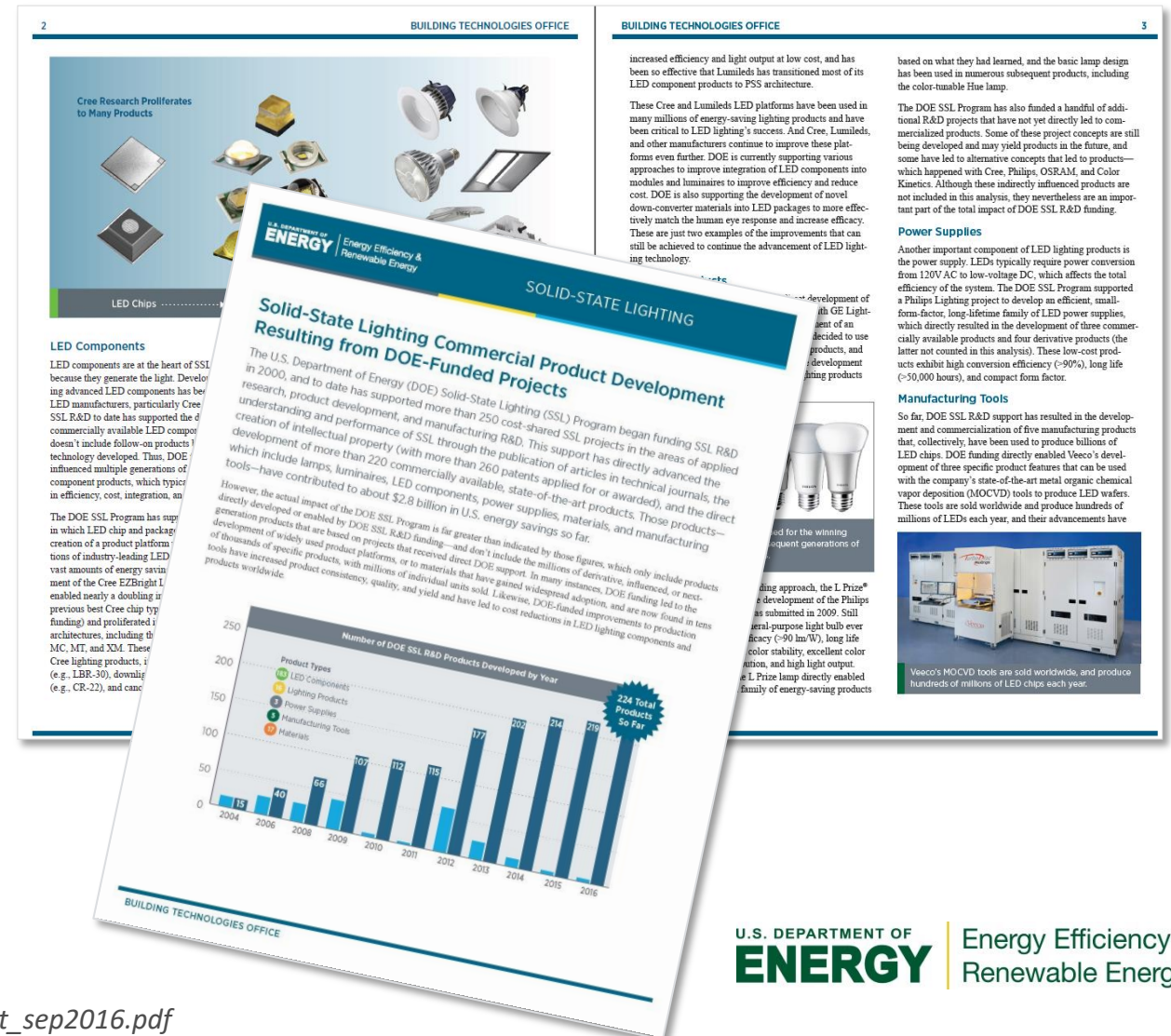
- For more information on nonprovisional patents, see: <http://www.uspto.gov/patents/resources/patents/np-patent-filing/>
- For more information on provisional patents, see: <http://www.uspto.gov/patents/resources/patents/provisional-patent/>
- For more information on PCT and international patents, see: <http://www.uspto.gov/patents/international-patents/>

BUILDING TECHNOLOGIES OFFICE

Huge Industry Footprint

More than **220** products can be directly traced to DOE-funded SSL R&D

Millions of LED products have DOE R&D inside
280 tBtu of energy saved in 2015

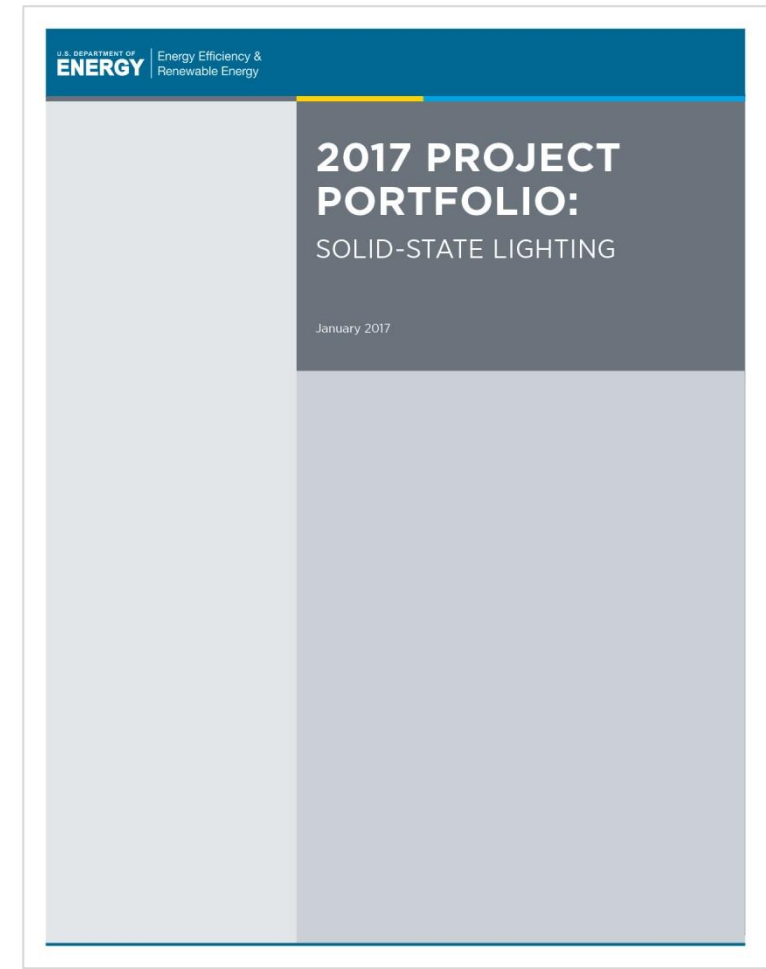


Broad Mix of R&D Partners

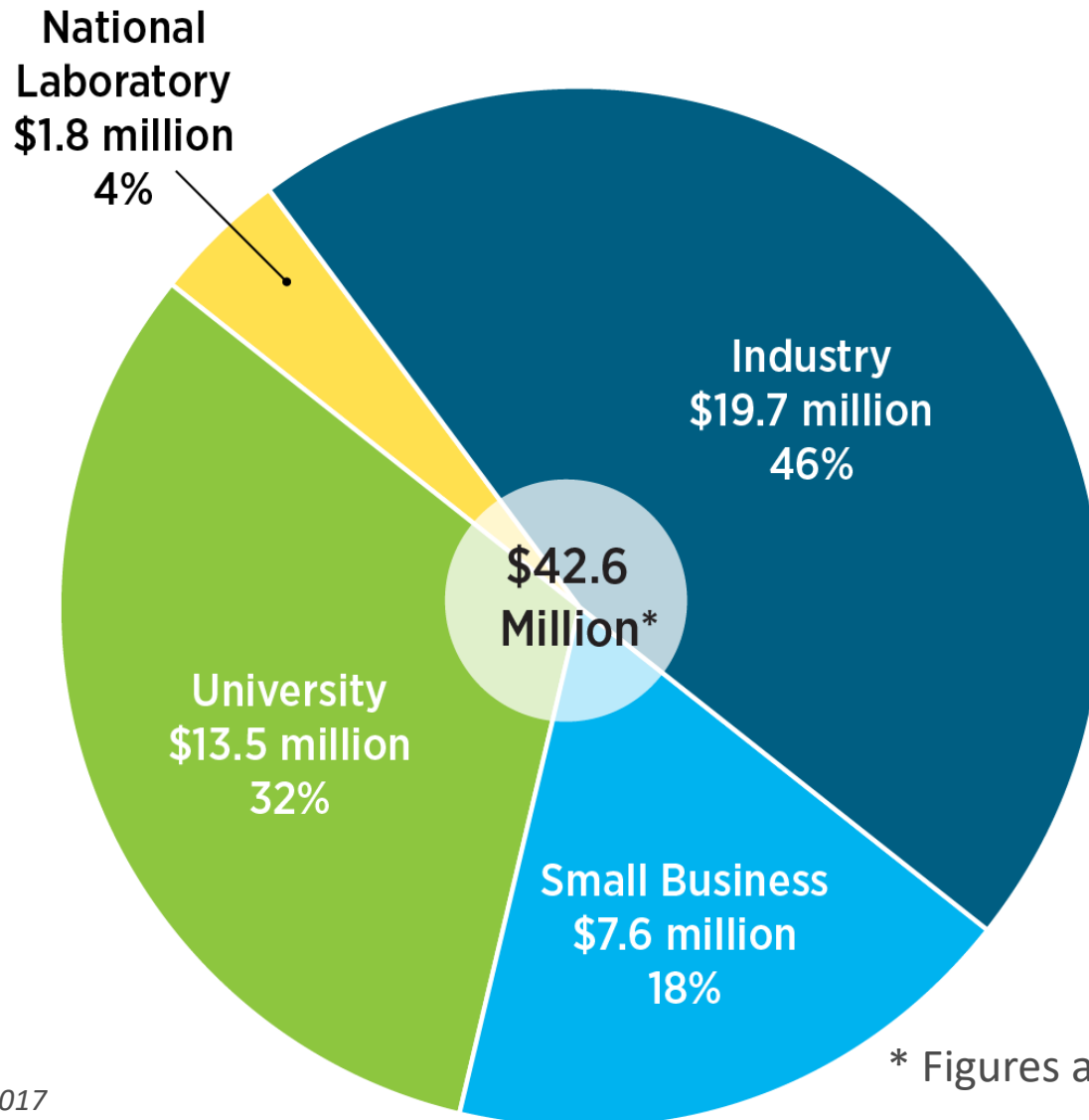


DOE SSL R&D Project Portfolio

- Results-oriented, competitively selected R&D projects
- Total current project value: \$42.6M
 - OLED: \$20.2M (13 projects)
 - LED: \$22.4M (14 projects)
- Industry and university partners provide average of 28% cost share



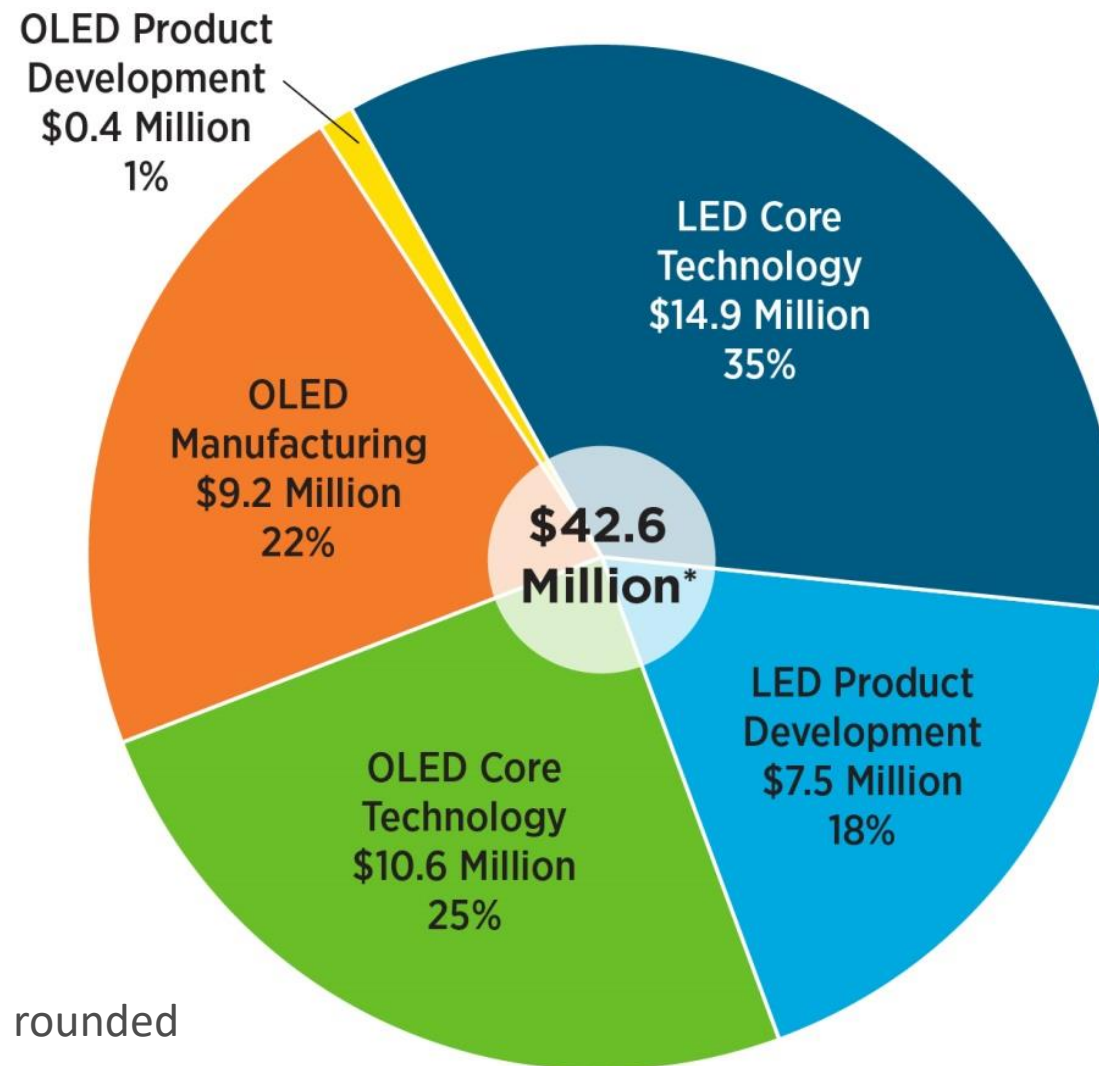
Recipients of SSL Program Investments



DOE funds SSL R&D in partnership with large and small companies, academia, and national labs

* Figures are rounded

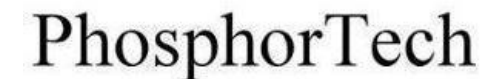
Breakdown of Funding by Focus Area



* Figures are rounded

Success with SBIR

- \$44M in SBIR SSL funding since 2000
- 137 awards in total
 - 96 Phase 1 awards
 - 41 Phase 2 awards
- Projects conducted by small companies; objectives align with DOE SSL R&D Plan



FY16 Highlights



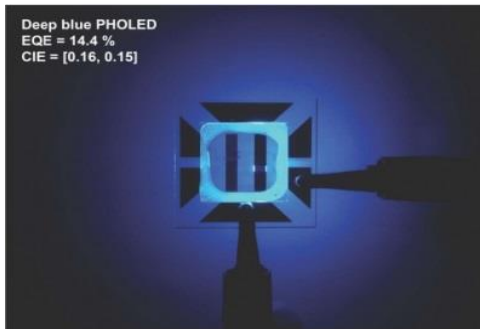
Lumileds develops high-voltage LED light engine with integrated driver



Philips develops innovative patient room lighting system with spectrally adaptive controls

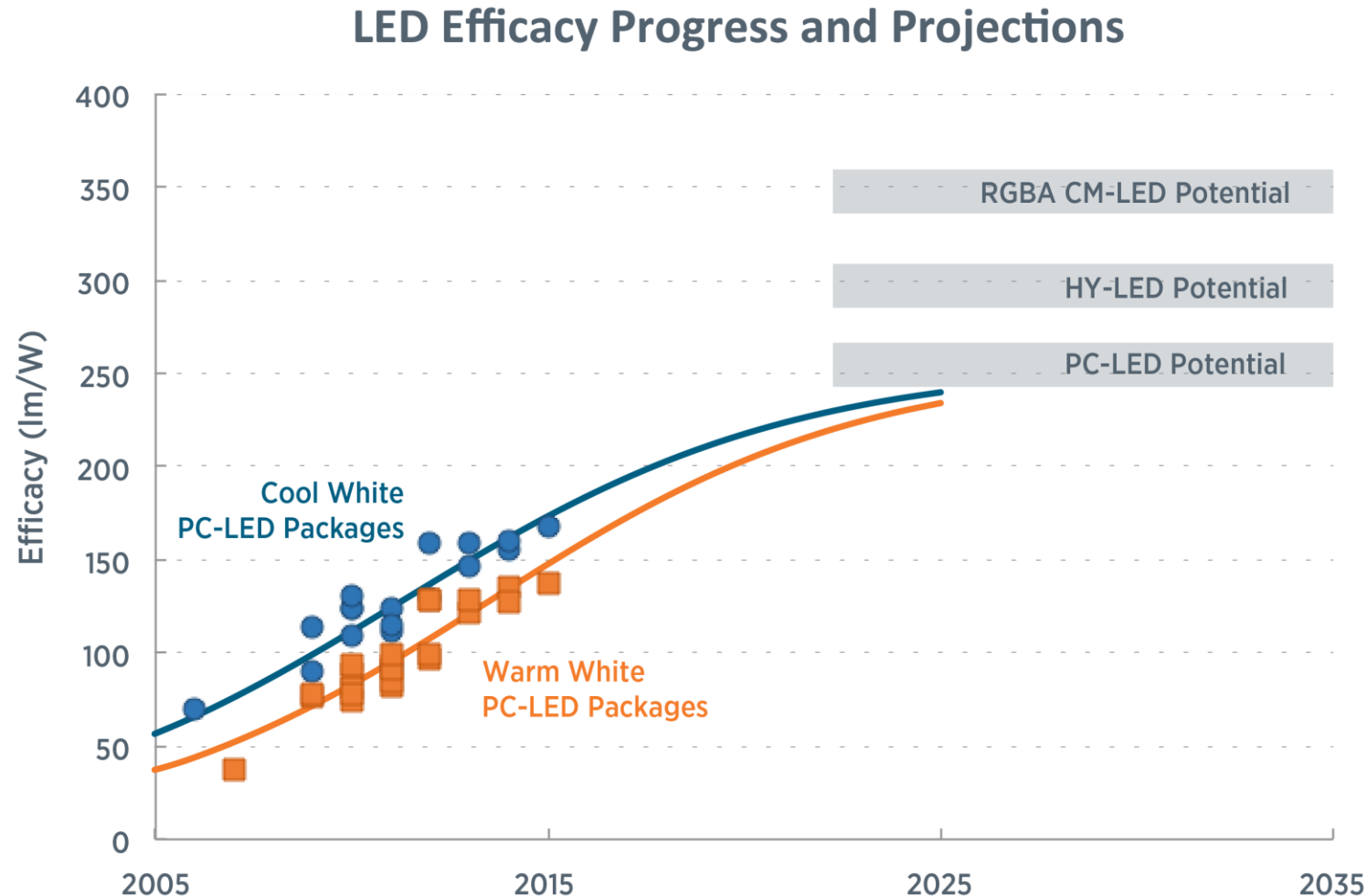


Acuity develops OLED luminaire with panel-integrated drivers and advanced controls



University of Michigan develops innovative strategy for increasing lifetime of blue phosphorescent OLEDs

Program Targets



Best-performing LEDs
are only halfway to
DOE goals

Significant technology
development
headroom remains

Top Performers from LED Lighting Facts® Database



Orion Ison High Bay Fixture
209 lm/W

Cree ZR22 Troffer
153 lm/W

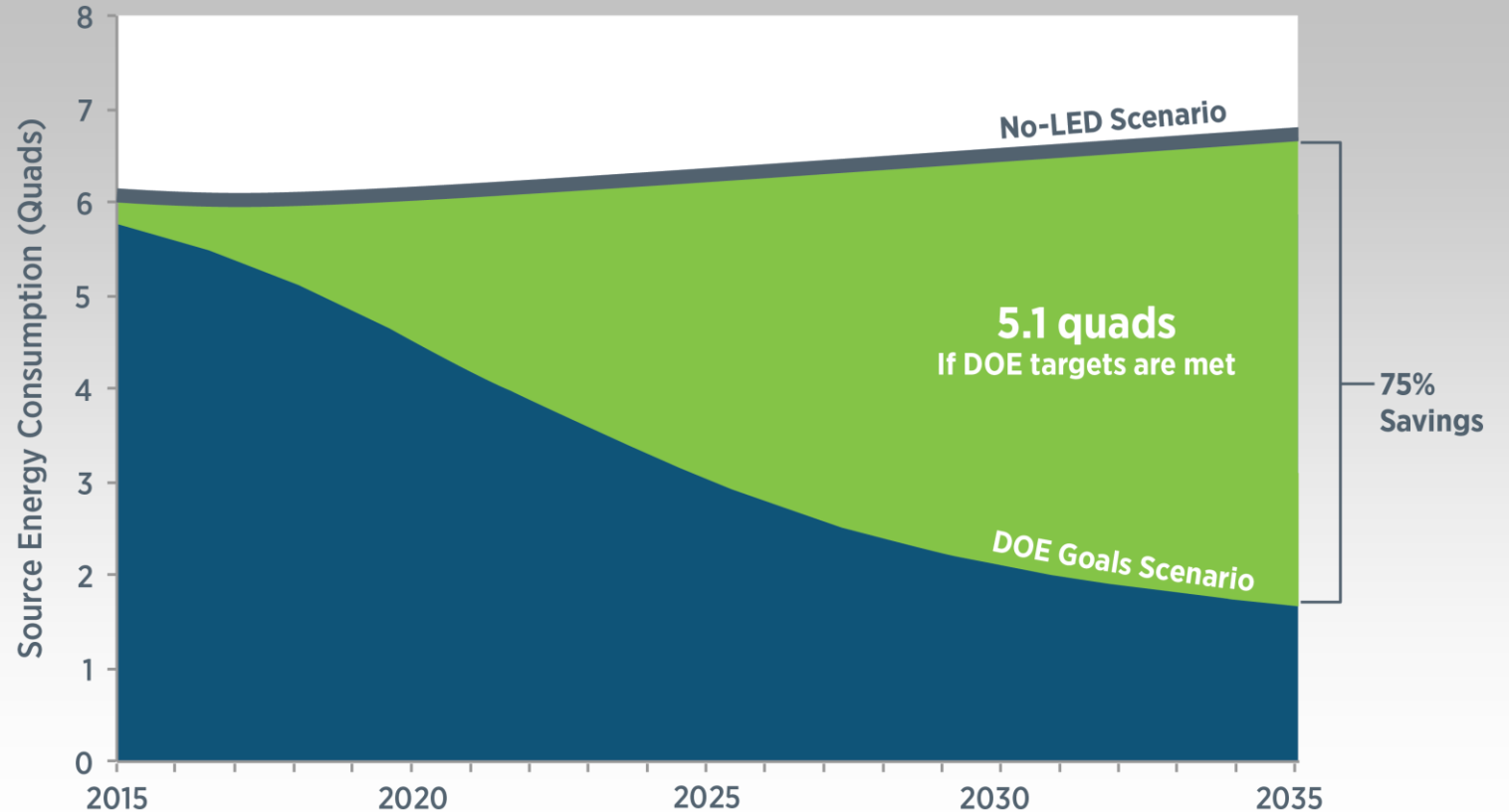


MaxLite Vapor Tight Linear Fixture
153 lm/W

The Big Picture

TURNING **DOWN** LIGHTING ENERGY USE

U.S. energy savings attributable to LED lighting will reach 5.1 quads by 2035. Energy use for lighting in 2035 will be **75% lower** than it would have been if LEDs had not entered the market.



LED Efficacy: What America Stands to Gain

The background of the slide is a stylized, dark blue representation of the American flag. It features a field of white stars on the left and wavy horizontal stripes on the right. A thin horizontal bar with a green-to-yellow gradient is positioned just below the title.

1. Enormous energy savings
2. Far-reaching scientific and technological advances
3. Better LED products with improved lighting quality
4. Lower first-costs for LED products
5. Stronger positioning of domestic manufacturing



The difficult is what takes a little time;
the impossible is what takes a little longer.

– Fridtjof Nansen, Explorer