



DOE Solid-State Lighting Program



Modest Investments, Extraordinary Impacts

Suddenly, solid-state lighting seems to be everywhere. Yet SSL technology is actually in its infancy. When it comes to U.S. energy savings, almost 90 percent of its potential remains untapped.

Shaping the Future of Solid-State Lighting

Today, LED (light-emitting diode) technologies illuminate grocery display cases, make parking garages brighter and safer, and proliferate on retail shelves. Homeowners and businesses are making the switch to SSL at an ever-faster pace, as product costs fall and performance keeps improving. The result: Americans are already saving hundreds of millions of dollars on energy, while making our nation more energy secure.

Despite these successes, most of the potential benefit of SSL is yet to come.

Fully capitalizing on the promise of LED and OLED (organic LED) technologies will catapult our nation forward in sustaining a strong energy future. Energy-efficient technologies like SSL not only conserve our nation's domestic energy reserves, they go hand in hand with making new energy technologies more competitive. For example, by substantially reducing electricity use for lighting, SSL will make it far more affordable and practical to construct zero-energy buildings—buildings so energy efficient that distributed systems can offset all or most of their annual energy consumption.

Still, the future of SSL is anything but certain. Will technological improvement continue at a rapid pace, enabling our nation to realize the full potential energy savings of SSL? And will we reap the maximum possible business and job growth, by attracting companies to locate engineering and manufacturing operations in the United States?



DOE-sponsored **workshops** bring together researchers, manufacturers, lighting users, energy efficiency programs, and other stakeholders to share up-to-the-minute data on SSL technology advances. Stakeholder input helps shape DOE R&D and technology development strategies.

Many hurdles stand in the way, requiring breakthroughs in materials, processes, control systems, product design, and manufacturing. These are the challenges being tackled by the U.S. Department of Energy (DOE), in partnership with industry, through the Solid-State Lighting Program.

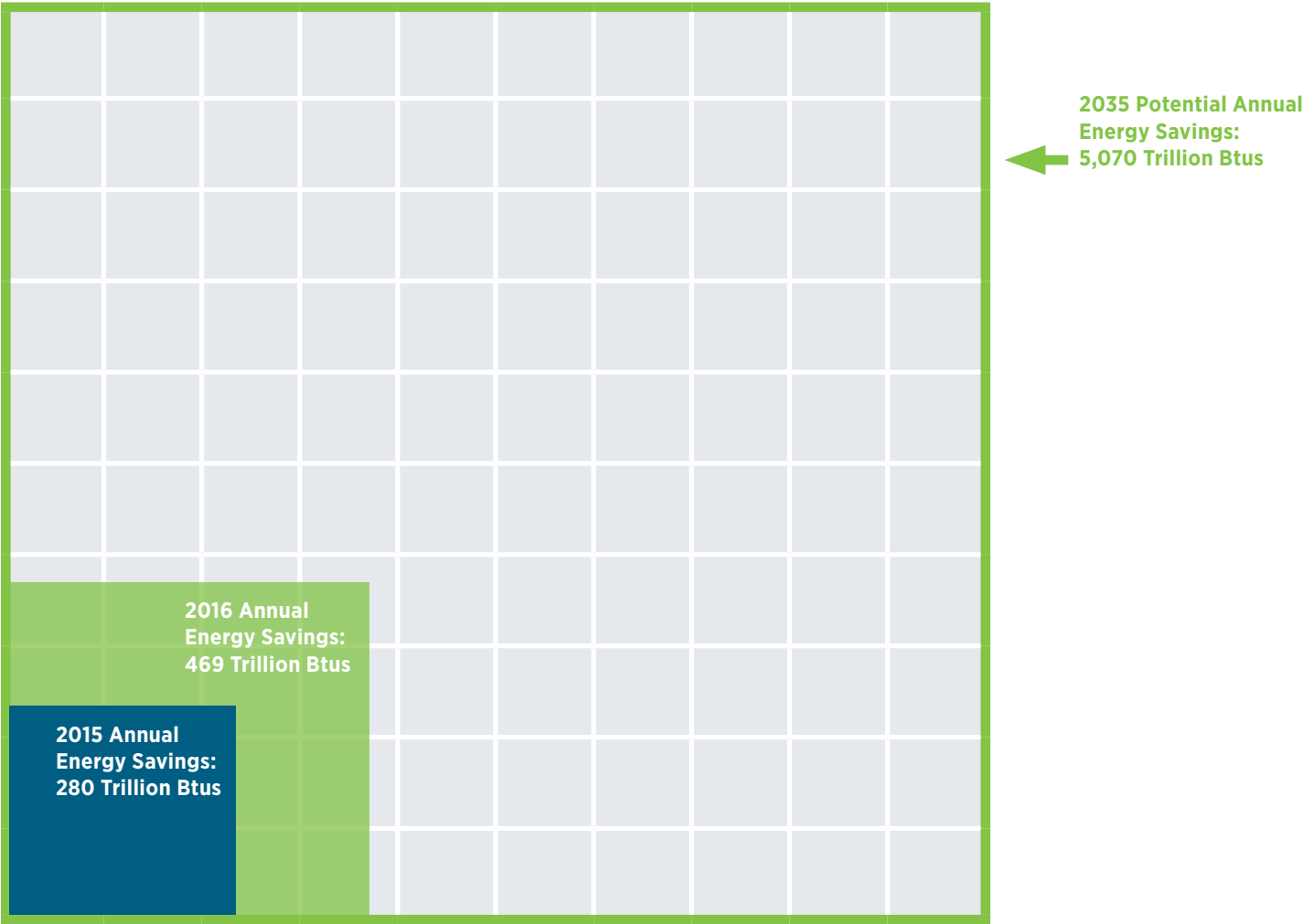
DOE strategies build on a strong record of progress.

In the past decade, modest yet highly strategic investments by DOE have helped make the United States the epicenter of SSL innovation. DOE has stimulated

▼ **These are still early days for SSL.** When it comes to U.S. energy savings, almost 90 percent of its potential remains untapped. In the best-case scenario, annual savings could grow from 469 trillion Btus in 2016 to an ultimate level of more than 5,000 trillion Btus by 2035.

the industry to achieve rapid improvements in efficacy, cost, and value-added features in SSL products by investing in competitively selected cost-shared R&D projects that reduce the risks of early-stage technology development; and by providing manufacturers with objective insights into product performance in order to fuel ongoing technology development. Along the way, DOE has continually evolved its program strategies and investments, to keep pace with technological progress and to deliver the best possible benefits for U.S. taxpayers.

DOE has set a high bar for SSL in the next decade, challenging the industry with aggressive goals for efficacy and performance, and cultivating the climate of innovation essential for new SSL-related business and job creation in the United States.



Btu: British thermal unit

Sparking a Lighting Revolution

Only a decade ago, solid-state lighting was generating virtually no illumination. Yet it **was** generating plenty of excitement. Scientists had documented the prospects for LEDs and OLEDs to produce high-quality white light at far greater levels of energy efficiency than traditional lighting technologies.

At the direction of Congress, DOE charted a pathway for rapidly moving SSL from the laboratory to the marketplace, in partnership with leaders in industry and academia. The driving purpose of DOE's involvement was to move the industry farther and faster, toward higher levels of efficiency and quality than would otherwise be achieved.

Wise federal investments: making a real difference.

Through the Solid-State Lighting Program, DOE has worked in close collaboration with innovators in the field, to topple technical and design barriers and to lay the foundation for early market successes.

Many barriers have been successfully tackled:

- The first market-available white LED products tested by DOE in 2006 were no more efficient than the incandescent bulb, yielding less than 20 lumens per watt (lm/W). Today, DOE's LED Lighting Facts® database lists nearly 290 LED luminaire products with efficacies greater than 160 lm/W. The most efficient LED luminaire reaches an efficacy of 209 lm/W.
- Initially, only narrow niche applications of LEDs offered cost and performance benefits. Today, LED products are becoming competitive in a wider range of applications. Specially designed LED luminaires—capable of delivering far greater efficacy than traditional luminaires—are starting to gain market share.
- Early buyers lacked the trusted metrics and uniform standards to make sound decisions about where and how to use SSL. Today, the whole lighting industry has climbed the learning curve. Supported by DOE's technical expertise and partnership with standards organizations, the industry now has essential tools such as industry-standard test procedures and product qualification programs.



The **Next Generation Lighting Systems competition** focuses on evaluation of connected lighting systems in real-world settings. Ongoing evaluations in a “living lab” offer valuable insights to improve the way these systems are designed, installed, and used.

- DOE recognized early on that, without focused action, American leadership in SSL technology would not necessarily translate into domestic manufacturing operations and jobs. Today, thanks to strategic investments by DOE and partners in efficient, flexible manufacturing technologies, the United States can be highly competitive as a location for SSL engineering and production.

What's the bottom line?

Program accomplishments to date have been impressive. Just consider, almost 290 R&D projects funded to date have resulted in more than 270 patents applied for or awarded and a huge industry footprint, with literally millions of SSL products currently on the market that are based on at least some DOE-funded R&D. Those products have contributed to

▼ New SSL products are being introduced at a blazing pace.

Yet, through 2016, energy-saving impacts have been minimal. Only a handful of niche products have gone beyond small, early market penetration over the course of 20 years. Ongoing improvements in performance and cost will be essential for more product categories to gain market share and start delivering significant energy savings.

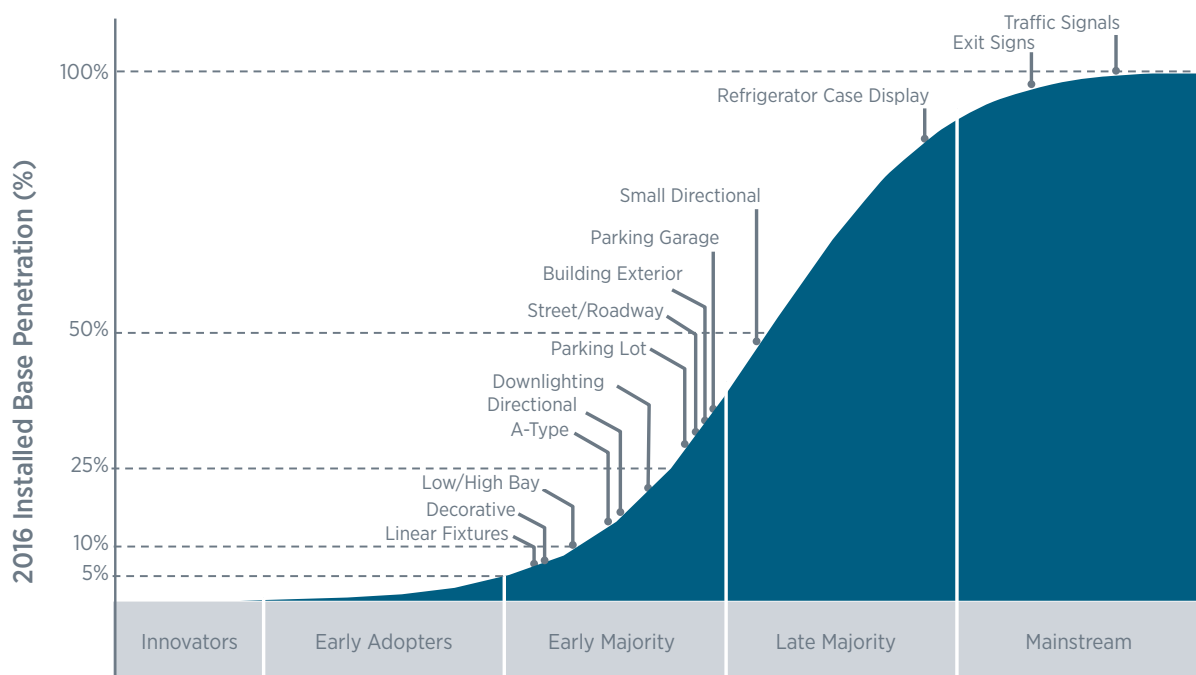
more than \$4.7 billion in U.S. energy savings to date—a remarkable return on the total DOE investment of about \$400 million.

Strong returns for U.S. taxpayers.

The DOE has structured the Solid-State Lighting Program to generate the best possible “bang for the buck” for U.S. taxpayers. According to a 2013 National Academy of Sciences review, the program is delivering exactly that:

DOE has done an impressive job in leveraging a relatively small level of funding to play a leading role nationally and internationally in stimulating the development of SSL.

With ongoing progress, the benefits of program accomplishments will compound over time. By 2035, SSL could potentially reduce national lighting electricity use by 75 percent. Compared to a scenario in which SSL had not entered the market, this reduction is equivalent to an annual savings of 5,070 trillion Btus, worth \$50 billion in today's dollars. That would equate to the total energy consumed by 45 million American homes today.



Keeping a Foot on the Accelerator

Although solid-state lighting has come a long, long way in a short time, the upside potential remains extraordinary. DOE has been instrumental in driving the industry forward. Now, by keeping a foot on the accelerator, our nation stands to magnify the benefits of SSL in saving energy and enhancing our built environments.

What's ahead for solid-state lighting?

For DOE, realizing the full potential for energy efficiency improvements will remain front and center in setting priorities for targeted cost-shared R&D projects. Innovation will be essential in unlocking new levels of performance. For example:

- There is still substantial headroom for improving LED lighting efficiency. Researchers believe that phosphor-converted and hybrid LED packages can achieve peak efficacy around 250 lm/W using standard drive conditions. With further breakthroughs in research on multicolor sources, efficacy will be pushed to 350 lm/W.
- OLED technology is less mature than LED technology, and with price still one of the biggest hurdles to widespread adoption, DOE works with industry to reduce costs through improvements in manufacturing equipment and processes.

Going forward, R&D priorities will include breakthrough improvements to efficiency, color quality and consistency, and lighting system performance, as well as value-added features that increase the benefits of SSL products. R&D also will target flexible production, testing, and monitoring technologies that will position the United States for sustained growth and leadership in SSL engineering and manufacturing.



DOE lab testing and field evaluations of emerging SSL products identify and intercept technology limitations and performance issues early on, speeding the pace of technology improvements.

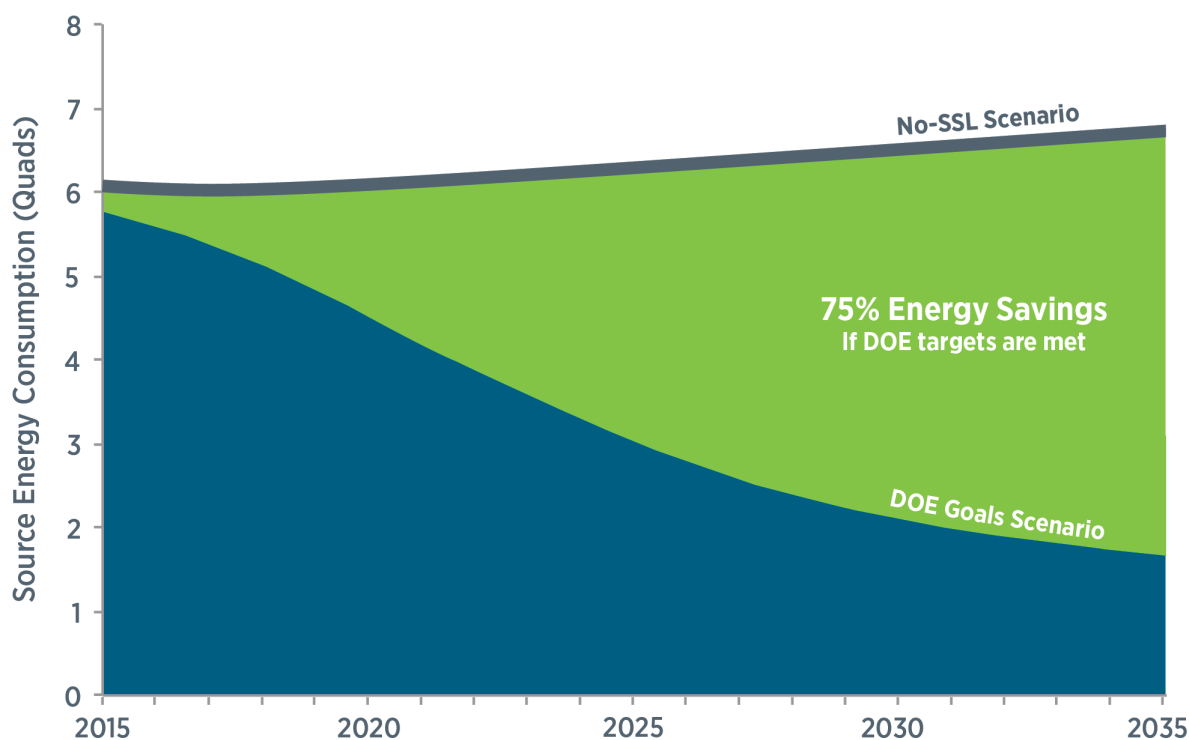
At the same time, DOE conducts foundational research to address gaps in our fundamental understanding of technology issues such as color rendition and sky glow impacts, and provides field and laboratory evaluations of emerging products. By identifying and characterizing performance issues in commercial products early on—and feeding that information back to manufacturers—DOE speeds the pace of technology improvement. An area of particular interest is connected lighting that integrates LED sources with network interfaces and advanced sensors and controls. Such systems can not only drastically improve the energy performance of lighting and other building systems, but also enable a wide array of services, benefits, and revenue streams that would enhance the value of SSL systems.

▼ **The DOE drives technology progress in SSL** by setting ambitious but achievable goals and co-funding vital research with industry partners.

DOE program strategies continue to keep pace with SSL technology.

Throughout the brief, exciting history of SSL, the DOE Solid-State Lighting Program has continually evolved to keep pace with the dynamic challenges of the industry. Yet two imperatives have remained constant: generating the greatest possible returns on taxpayer investments, and providing trusted, impartial data and analysis to guide researchers and manufacturers.

Moving forward, these same imperatives will continue to guide the program, as DOE invests strategically to open up new frontiers in SSL performance and to maximize benefits for our nation.



DOE Solid-State Lighting Program

The U.S. Department of Energy (DOE) is committed to realizing the full energy-saving potential of solid-state lighting. For more information, visit www.energy.gov/eere/ssl/.

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