

R&D Investments Build on Each Other to Boost Performance and Lower Cost of High-Brightness LEDs

Ten years of research projects partially funded by DOE have already paid off in millions of energy-saving products on the market.

Lumileds (formerly Philips Lumileds) is an integrated manufacturer of LEDs and LED modules, a growing number of which are used for general illumination. At Lumileds' corporate headquarters in San Jose, California, scientists and engineers are advancing the cutting edge of solid-state lighting technology through continual improvements to product efficacy and performance.

MARKET IMPACTS

of Lumileds' DOE-Funded R&D

In the last six years:

- Efficacy of Lumileds' warm-white high-power LEDs has more than tripled, from about 40 lm/W in 2008 to more than 120 lm/W in 2014.
- Over that same period, the price/klm of the company's warm-white high-power LEDs has dropped by a factor of six, from about \$15/klm to \$2.50/klm.

More than 200 successfully released product SKUs were directly or indirectly impacted by DOE funding.



The high-quality lighting in this factory uses Lumileds' LUXEON M LEDs, which were developed in part with the use of DOE funding and have been commercialized in a wide range of CCTs and CRIs. *Photo credit: Lumileds.*

Public-Private Partnership: A Recipe for Success

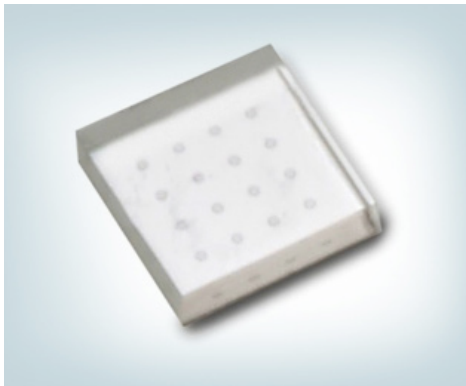
Building on Lumileds' innovative approach, DOE-supported R&D projects have contributed to boosting the performance of LED chips and modules on many fronts, while also lowering the cost. These improvements often proliferate into multiple Lumileds product lines, which to date have been incorporated into millions of LED lighting products on the market. For example, a DOE-funded project helped develop the LUXEON M LED product, which has been successfully commercialized in a wide range of

correlated color temperatures (CCTs) and color rendering index (CRI) values and enabled the 100W equivalent LED bulb—the first 100W equivalent to be qualified by ENERGY STAR®. The chip-in-frame concept developed in this project was also carried over to LUXEON T and LUXEON TX.

Another DOE-funded Lumileds project led to the development of a high-power warm-white hybrid LED package for high-efficacy, high-CRI LED products—leveraging the experience gained making the L Prize®-winning bulb to develop package-level color control electronics.

“DOE funding has helped to speed up our research and development in LED lighting by cushioning some of the risk. It has enabled some of our most successful products on the market today.”

— Jy Bhardwaj, senior vice president of R&D



Lumileds' LUXEON FlipChip LED, which was developed with the support of DOE funding, uses a patterned sapphire substrate to reduce cost.

Photo credit: Lumileds.

Still another project evaluated several different substrate technologies for LED manufacturing cost reduction, ultimately identifying patterned sapphire substrates as the most effective approach, which resulted in the development of die-level LUXEON FlipChip LEDs. Building on that approach, a subsequent DOE-funded project industrialized the in-house fabrication of patterned sapphire substrate LEDs and optimized the epitaxy process, reducing costs by up to 30% and cutting down on the need for labor-intensive LED packaging operations.

The primary value of the DOE funding, eclipsed many times over by Lumileds' own investments in these projects, has been to enable disruptive innovations in product development and manufacturing, which have helped make Lumileds a leader in LED technology and the worldwide LED market.

Creating U.S. Jobs

Lumileds does its front-end epitaxy manufacturing for high-power LEDs in San Jose and follows the principles of lean manufacturing, which emphasize eliminating waste while delivering quality products at least cost with greatest efficiency.

By helping Lumileds lower costs and improve performance across a wide range of LED lighting parameters, DOE funding has been instrumental in the company's emergence as an industry leader that has more than tripled its revenues in the past decade, reaching customers foreign as well as domestic with products that to date have saved billions in energy costs. ■



This Philips A19 lamp, which uses Lumileds' LUXEON M LEDs, was the first 100W-equivalent A19 lamp to be ENERGY STAR qualified.

Photo credit: Lumileds.

DOE SSL R&D INVESTMENTS

GOALS

1. Maximize the energy efficiency of SSL products in the marketplace.
2. Remove market barriers through improvements to lifetime, color quality, and lighting system performance.
3. Reduce costs of SSL sources and luminaires.
4. Improve product consistency while maintaining high-quality products.
5. Encourage the growth, leadership, and sustainability of domestic U.S. manufacturing within the SSL industry.

WHY IT MATTERS

- Technology innovation fuels U.S. economic growth and job creation.
- LEDs that are more cost-competitive will accelerate markets for energy-efficient solid-state lighting, saving energy for American homeowners and businesses while reducing carbon emissions.