

From LED Chips and Drivers to Packaging and Luminaires, R&D Investments Lead to Multiple Breakthroughs

More than a decade of research projects partially funded by DOE has led to advances in solid-state lighting that have improved the performance and lowered the price of millions of products on the market.

Cree is a vertically integrated manufacturer of LED chips and devices as well as lamps and luminaires for a wide range of applications. The vertical integration allows for close communication between the various teams at every step—from R&D to product development to each segment of the manufacturing process. About 50 Cree scientists work at Cree's R&D center in Santa Barbara, California, where, with DOE's continued support over more than a dozen years, advances in multiple aspects of solid-state lighting have been achieved. These advances have found their way into millions of energy-saving products on the market in a wide range of applications such as downlights, outdoor lighting, troffers, and replacement lamps.



The Cree Edge™ LED high-output area luminaire, a winner of the Next Generation Luminaires™ outdoor design competition, incorporates chip technology developed in part with the use of DOE funding and is saving energy while providing high-quality lighting in settings such as this car dealership. *Photo credit: Cree.*

Public-Private Partnership: A Recipe for Success

Building on Cree's innovative technology and novel design concepts, DOE-supported R&D projects have helped boost performance from LED chips, LED packaging, driver circuits, and luminaire systems. Often, these results have proliferated into multiple Cree product lines, after further development as well as cost and performance validation for commercial volume production. Cree's first DOE-supported R&D project, in 2001, focused on then-novel LED flip-chip designs that provided the foundation for a new generation of high-brightness LEDs, including XBright®

and XThin®. Another early R&D project contributed to the development of the highly successful EZBright® chip product line, which has become one of Cree's highest-volume lines. DOE investments supported improvements in LED package efficacy that contributed to the later development of the XM-L EasyWhite® family, as well as the development of a highly efficient driver architecture and breakthroughs in the design and fabrication of LED downlights, PAR38s, MR16s, and A19 lamps. After more than a decade, the company hasn't stopped

“Over the last 10-plus years, DOE SSL funding has supported and helped to accelerate Cree's innovation of cutting-edge LED technologies by sharing the development risk presented by early-stage R&D. Several DOE-funded technologies have contributed to a broad range of Cree's LED-based products.”

— Rob Glass, vice president of technology, materials, and optoelectronics at Cree

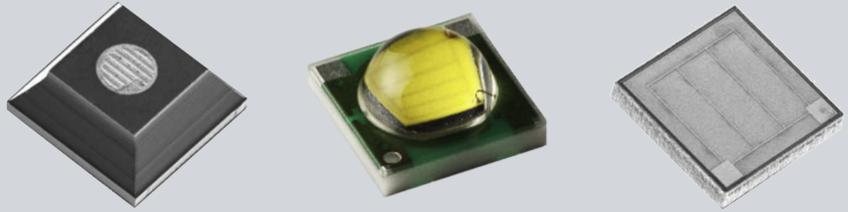
MARKET IMPACTS of Cree's DOE-Funded R&D

In the last 10 years:

- Cree blue (450nm) EZBright chip efficiency more than tripled, from ~20% to >60%.
- Cree white LED package peak efficacy more than tripled, from 50 lm/W to >150 lm/W.
- Cree driver cost decreased by more than 50%.
- Cree LED lamp/luminaire cost per kilolumen decreased 90%, from \$180/klm to \$18/klm.

DOE SSL R&D funding has contributed to the continuing evolution of Cree's LED chips (XThin®, left; XP LED, center; EZBright®, right), which have found their way into millions of products on the market.

Photo credit: Cree.



innovating, and the results can be seen in a wide range of SSL products that have helped move the market.

The primary value of the DOE funding, which is dwarfed by the amount of money Cree itself has invested in these projects, has been to share the risk of exploring new areas of solid-state lighting research and development. This enables the company to be more aggressive than it might otherwise be, in terms of leaving no stone unturned when looking for ways to move the technology forward.

Creating U.S. Jobs

Cree does its manufacturing at three U.S. facilities: two in Durham, North Carolina, and another in Racine, Wisconsin. One of the Durham facilities is the main campus, where the chips are made and where electronic components—such as the integral power supply and some LED boards—are assembled. The other Durham plant is a newer location, where the replacement lamps are assembled; the Racine facility, a legacy of Cree's 2011 acquisition of Ruud Lighting/BetaLED, is used for the assembly of troffers and streetlights.

Approximately 60% of Cree's SSL manufacturing is done domestically, with the rest done in China—where the LEDs are packaged into devices and some smaller fixtures are assembled. The company has worked to offset higher overseas

domestic labor costs by designing its products for manufacturability. About 2,000 people are employed on Cree's main campus, with the newer Durham facility employing another 200 and the Racine location an additional 1,000.

By helping Cree lower costs and improve quality across a wide range of LED lighting parameters, DOE funding has been instrumental in the company's emergence as an industry leader that has increased its revenues by over 350% in the past decade, reaching customers foreign as well as domestic with products that to date have saved billions in energy costs. ■



Thanks in part to an LED design developed with the help of DOE funding, Cree was able to reduce the cost of its energy-saving 60W-equivalent LED replacement bulbs to the point where they retail for less than \$10. *Photo credit: Cree.*

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.