LED WATCH

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GOOD ISN'T QUITE GOOD ENOUGH

A DOE white paper examines what we stand to gain by increasing LED efficacy

The rapid and substantial gains in efficacy shown by LED lighting products over the past few years might prompt some people to question the need for further targeted improvements in this area. Today's high-performing LED devices can produce 160 lumens per watt, with most high-performing LED luminaires achieving 125 to 135 lm/W. And while those figures fall considerably short of the U.S. Department of Energy's (DOE) goals of 250 and 200 lm/W, respectively, some might reason that the technology could already be considered "good enough" to work in most lighting applications—so why bother investing more time and money into pushing the efficacy needle further along the dial?

Well, as it turns out, there are five compelling reasons for doing so, only one of which has to do with energy savings. Those reasons are spelled out in a DOE white paper on the topic, which is posted online at *www.energy.gov/eere/ssl/downloads/led-efficacy-what-america-stands-gain*:

- **Better lighting products with improved lighting quality.** Greater LED efficacy enables more light to be produced with less electrical power at lower operating temperatures. As a result, manufacturers and designers can choose to reduce the light-source size, decrease the number of LEDs, increase light output for a given source size, reduce electrical power input, reduce the amount of generated heat, or various combinations of the above. In short, increased efficacy creates headroom for improving quality, performance, longevity and reliability; lowering costs; and adding new services that can be delivered through integration with controls and intelligence. Where each manufacturer goes with that headroom in creating competitive advantage is up to them, but the opportunities cross a host of interrelated dimensions, including optical control, glare mitigation, color stability, lumen maintenance and new features.
- **Lower first costs.** Although in a growing number of market niches LED products are becoming increasingly competitive against incumbent lighting technologies on a life-cycle cost basis, most remain at a notable disadvantage on a first-cost basis. With continued R&D, LED products not only can compete head-to-head on first cost, but have the potential to be less expensive than many incumbent lighting technologies. Greater efficacy is the key to these cost improvements.

  Already, LED manufacturers estimate that one-third of the cost reductions accomplished to date in LED lamps and luminaires can be attributed to efficiency improvements. Further decreasing the number of LED packages needed to deliver a given light-output level enables lower input power, cutting the cost of the power supply. It also minimizes the amount of thermal handling materials and heatsinking needed for a luminaire, and enables the optical system to be simplified and desired optical performance to be achieved at a lower cost. All these factors can dramatically reduce costs and accelerate change-out of the existing lighting stock.
- **Far-reaching scientific and technological advances.** In advancing LED efficacy, researchers will continue to realize scientific and technological progress on multiple fronts. Research into improved LED efficiency already has yielded valuable insights into materials science, semiconductor physics, phosphor materials, quantum dots, power-supply components and optical materials. This research is likely to have significant crossover into other clean-technology, consumer and communications applications.

One example is the progress on gallium nitride (GaN) electronic devices that has emerged from efforts related to LED manufacturing. Now making headway as high-efficiency power converters for large-scale photovoltaic and wind power-generation facilities, GaN power electronics also will likely be used in most hybrid and electric vehicles, due to their thermal stability and power-conversion efficiency. Even seemingly intractable challenges in LED R&D are spinning off scientific innovations.

Today, the operating performance of LED lighting products is limited by "droop," an efficiency falloff that occurs with increasing current density in LEDs. In exploring droop in indium gallium nitride (InGaN), researchers in the DOE program have developed new semiconductor physical models and experimental methods that are proving valuable in other fields.

Similarly, researchers are tackling the mystery of the "green gap," in which LEDs become less efficient as their emission wavelength is pushed from blue to green wavelengths. Investigations in this area are very likely to yield fundamental insights that open new directions for advancing semiconductor technology. And quantum dots (nanoscale semiconductor optical converters) found their first commercial application with solid-state lighting and still hold promise for improving LED efficacy, but in addition are now being used to boost energy and color-quality performance in televisions and displays and have possible application in solar cells.

- **Stronger positioning of domestic manufacturing.** Efficacy-driven research can specifically benefit the competitive position of domestic LED manufacturers, who have focused on producing high-value, high-brightness LEDs, while Asian manufacturers have focused on lower-cost, mid-power LED products. Currently, many LED lighting product integrators are finding it cost-effective to use the mid-power LED packages as a light source. These products can have very good efficacy at low current densities, but suffer from droop at higher current densities, requiring a large number of smaller LEDs to reach typical lighting levels. If droop efficiency losses can be mitigated, high-brightness LED packages can be run at even higher flux levels per package, reducing their effective cost per lumen. This would alter the cost-performance trade-offs between mid-power and high-brightness LEDs, to the clear benefit of domestic LED manufacturers.
- **Enormous energy savings.** If industry reaches DOE's LED efficacy targets of 250 lm/W for devices and 200 lm/W for luminaires, the country will realize annual savings of 4.5 quads of primary energy by 2030, yielding $40 billion in annual cost savings in today's dollars. Without a concerted effort to boost efficacy, there would be some incremental increases, but market pressures to decrease costs and fill existing sockets would likely trump industry investment in technology progress and design innovation, locking in current-performance-level products for decades.

MARKET ACCEPTANCE

If we're to realize the full energy-savings benefits from LED lighting, a continued focus on efficacy will be essential, along with the rapid translation of that progress into high-quality, cost-competitive products that achieve broad market acceptance. The marketplace has been receptive to LED lighting products in sectors where they provide performance and life-cycle cost advantages over incumbents. Now, in addition, manufacturers need a compelling value proposition that gets early adopters to upgrade from 2010-era products to future, much-better-performing products. With more efficacious LEDs, manufacturers and designers can create the high-value products and applications that will keep buyers coming back for more.

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