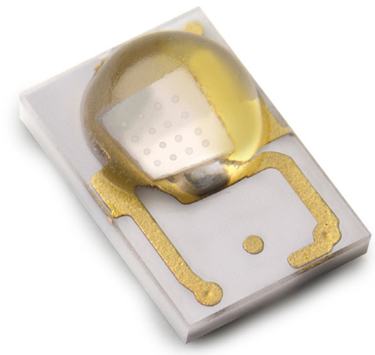
WHITE PAPER

Street Lighting

LEDs: coming soon to a street light near you



The Performance, Design and Cost Benefits of Power LEDs in Street Lighting

LEDs have been taking to the streets since the 1990s, when cities throughout the U.S. and Europe began replacing incandescent-based traffic lights with highly energy-efficient solid state fixtures. Today's power LEDs are poised to cross the next municipal frontier and tackle the challenge of street lighting. If the mass adoption of solid state traffic signals is any indication, high pressure sodium, and high intensity discharge (mercury vapor) street lamps may soon lose their luster as the dominant sources of road and sidewalk illumination.

The first LED street light installations are already being tested around the world, and in some cases implemented, in China, North America and Europe, as governments, municipalities and utilities strive to replicate the energy and maintenance savings of LED traffic lights elsewhere within their borders.

With a 10- to 15-year lifetime that is at least triple that of current technologies, the maintenance advantages alone offer a street-smart argument for transitioning to LED-based systems. When we consider the design flexibility and sustainability afforded by LED-based systems, the case for solid-state street lighting is compelling. LED solutions offer energy savings of as much as 50%, other 'green' features are mercury-free construction, and reduced light pollution made possible by the ability to precisely control light direction through LED placement and optics optimization.

Moreover, street lamps using today's power LEDs are fully capable of meeting standard regulations for luminance levels and uniformity. LED solutions, unlike many other technologies, provide a sufficiently even light distribution (as shown in Figure 2) to meet recommended street light uniformity levels. This is a valuable benefit that is capable of eliminating glare, hot spots and related visibility, safety and energy-wasting problems. Even light distribution improves the street lighting function and creates a better environment for people.

All of these factors add up to make solid state street luminaires a bright idea.

Sample Design Scenario

To examine the performance benefits of using LEDs for street lamp illumination, let's look at a demonstration lamp built with LUXEON Rebel LEDs (Figure 1). In this design, 50 cool white (6500K) LEDs are placed in rows and installed at varying angles to achieve the desired light coverage. Each LED is driven at 350mA, has a light output of roughly 90 lumens, and uses a secondary collimating optic for maximum efficiency and uniformity.

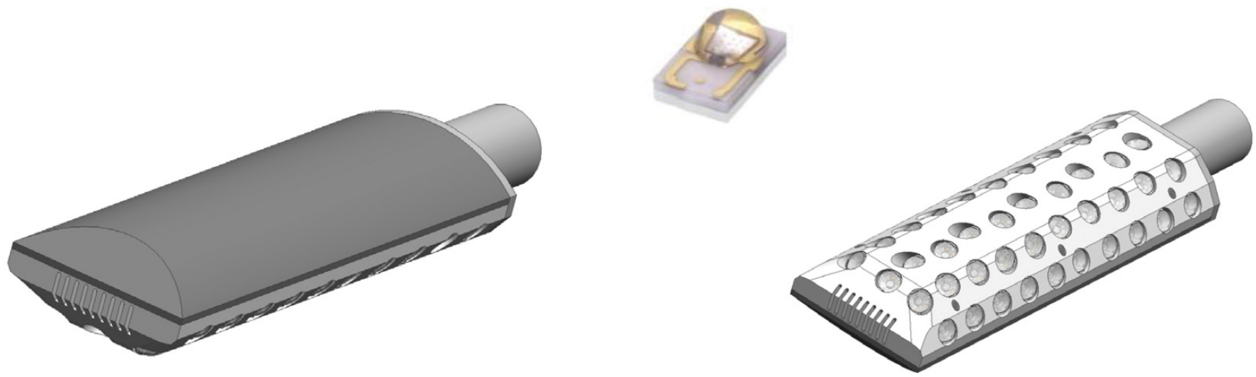


Figure 1. Solid-state street lamp demonstration design with LUXEON Rebel.

This configuration was designed to comply with European specifications for residential and city center street lighting, including average luminance levels and overall luminance uniformity, while also minimizing the number of LEDs required and saving energy over conventional light sources.

All of the European benchmarks were reached and in some cases exceeded, proving that today's power LEDs are not only appropriate but superior for many pedestrian and street lighting solutions.

In addition, the demonstration design produced an LED junction temperature of 62°C, well within the range required to achieve the 60,000-hour life expectancy of the LUXEON Rebel LEDs used in the model.

The LUXEON Rebel was chosen for demonstration purposes because of its ultra-small footprint (75% smaller than other surface mount power LEDs), high operating junction temperature, leading lumen performance and 60,000-hour lifetime, drive current range of 350mA to 1000mA, and availability of cool, neutral and warm white options for varying street light environments. The small size and form factor of the package enabled maximum light and packing density as well as exceptionally tight coupling of the optic to the LED — both critical factors in achieving desired luminance levels while also minimizing flux loss caused by diffraction of light through the optical lens.

What follows is a discussion of the comparative performance of the sample LED street lamps against those built with the present street light technologies, plus a look at additional benefits that are expected to spur a movement toward power LEDs in street lighting.

Performance Benefits

The chart below (Figure 2) shows how the solid-state street light demonstration design produced with LUXEON Rebel LEDs stacks up against the two dominant lighting technologies used for street lighting.

	LUXEON REBEL	HIGH PRESSURE SODIUM	MERCURY VAPOR
Flux (lm)	3325	5510	4340
Power consumption	67W	90W	138W
System Efficacy (lm/W)	50	61 *	31
Average lux	14	19	14
Utilization	0.0042	0.0034	0.0032
Lux/W	0.21	0.21 **	0.10
Min/avg lux ratio	0.40	0.32	0.23
Lifetime (hours)	60,000	20,000 to 30,000	6,000 to 10,000

Figure 2. Performance of LED demonstration design and conventional street lamps.

The performance benefits of the LED scenario are striking. Highlights include:

- **Lower power consumption (67W)** slashing energy use by 52% over Mercury Vapor (138W) and 26% over a high pressure sodium fixture (90W)
- **Higher efficacy (50 lm/W)** far exceeding mercury vapor's 31 lm/W and again contributing to energy savings.
  - The higher efficacy measurement for high pressure sodium lamps is misleading because it includes wasted light that in turn wastes energy, as described below.
- **More lux per watt (0.21)** more than double that of a mercury vapor street lamp.
  - The LED-equivalent measurement for high pressure sodium lamps is skewed by hot spots that bump up the lux rating but cause undesirable visibility, safety and glare problems (see Figure 4).
- **More even light distribution (0.40)** than either of the other alternatives, as indicated by the ratio between the minimum and average lux produced in the target zone. The LED scenario was the only one of the three to match the European street lighting guidelines on this uniformity measure because of its ability to precisely direct light (see Figure 4).
- **Longer lifetime (60,000 hours)** translates into a 10- to 15-year life expectancy, depending on the duration of darkness in the specific geographic location. In contrast, conventional street lamps burn out after three to five years, incurring higher manpower and related maintenance costs for bulb replacement.

Lower Total Cost of Ownership

Beyond performance, one of the most compelling arguments in favor of LED street lamps is the cost advantage of operating and maintaining the fixtures. In part, this comes from reduced energy usage that can cut electricity bills in half. In part, it comes from the longer replacement cycle made possible by longer LED life. Increasing the interval between bulb replacements from three to five years to 10 or 15 means fewer truck runs, less fuel, and less overhead for work crews.

This in turn accelerates the return on investment. Even with the higher initial cost of a solid state luminaire, municipalities can recoup the costs of an LED-based street lighting installation in four to six years (see Figure 3).

The ROI will be even faster as power costs increase and technology advances increase LED light output, making it possible to deliver more lumens per watt for additional energy savings.

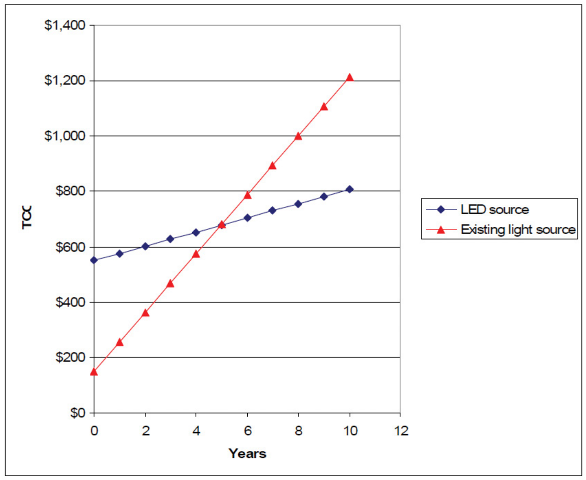


Figure 3. Estimated payback times.

Reduced Light Pollution

Another virtue of LED-based street lighting is the ability to all but eliminate hot spots and wasted light. This degree of control over the light distribution — a byproduct of the LED form factor itself — not only improves safety and visibility but also reduces the lumen requirements of the luminaire. Consequently, the use of LEDs delivers energy savings above and beyond that made possible by their low power demands.

A traditional filament emits light from a single source. Shields, reflectors and/or lenses are used to point the beam in the desired direction, but engineers have limited control. Some light spills over to neighboring buildings or bounces skyward (wasting energy and creating light pollution), the light is brighter in the middle and dimmer at the edges, and the light concentration in the center creates hot spots that can cause eye strain for drivers and pedestrians.

In contrast, the small LED package allows the use of multiple light sources with individual optics. Each LED can be targeted to a specific area or position, providing more uniform coverage as well as eliminating central hot spots and glare. It's like the difference between having a single massive spotlight pointed at a stage and aiming multiple smaller spots at strategic locations.

In the demonstration street fixture under discussion, for example, 50 LUXEON Rebel LEDs are deployed at strategic angles and tightly coupled with optical lenses that point the light in varying directions to achieve relatively uniform coverage. Figure 4 below shows the dramatic difference in light distribution between street lamps built with LUXEON Rebel LEDs and those based on mercury vapor bulbs.

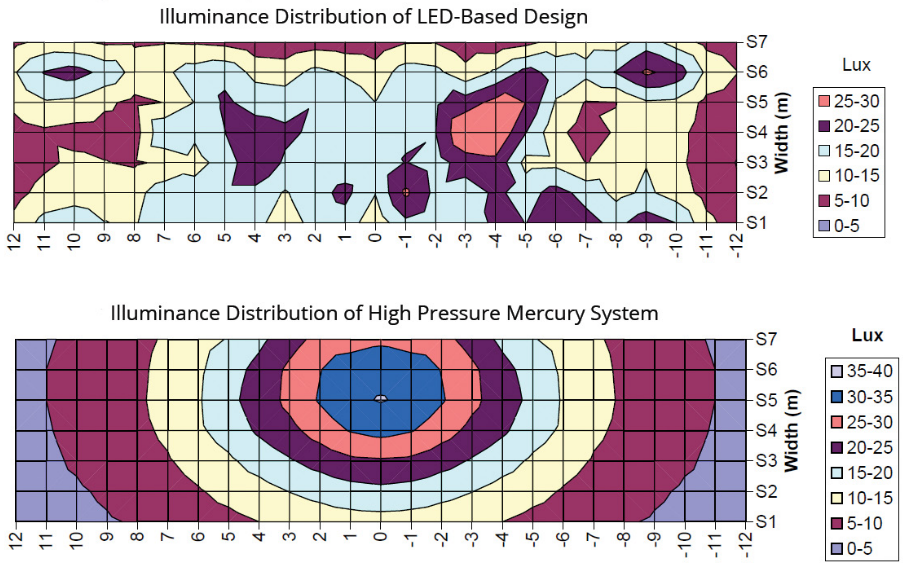


Figure 4. Light distribution of LEDs versus mercury vapor.

These diagrams provide an "at-a-glance look" at the comparative uniformity of the LED demonstration design and conventional solution across the target zone. While the mercury vapor example has a hot spot in the middle (corresponding to the area directly beneath the light pole) and very little illumination at the outer edges, the LED light distribution pattern avoids both extremes and instead remains relatively consistent. This is reflected in the earlier Figure 2 performance chart, where the demonstration lamp built with LUXEON Rebel LEDs surpasses both high pressure sodium and mercury vapor solutions for uniformity as expressed in the minimum/average lux ratio.

Low Environmental Impact

The use of LEDs for solid-state street lamps also provides a variety of sustainability benefits that facilitate compliance with 'green' initiatives. Among them:

- **Low LED power consumption** yields energy savings of 20% to 50% over high pressure sodium and mercury vapor street luminaires at today's levels, as indicated earlier. This energy efficiency is expected to increase with ongoing advances in solid state technology.
- **LEDs' ability to minimize wasted light** lowers power demands even further by reducing the lumen requirements for a given street fixture. Since light distribution can be controlled on an LED-by-LED basis, engineers can effectively light the target zone without the light pollution created by a single-beam solution.
- **Mercury-free LED construction** makes solid state street lamps safe for landfills while also complying with mercury bans such as the European Union's RoHS directive.
- **Long LED life** lengthens replacement cycles and associated fuel usage by maintenance crews, while also extending fixture life and thereby reducing the burden on the waste stream.
- **LED street lights reduce pollution and carbon footprint** via energy savings that lowers carbon dioxide and mercury emissions from coal-burning plants, as well as reduced fuel consumption by maintenance crews dispatched for bulb replacement.

Better Color Rendering and Color Temperature Choice

Finally, LED street lights offer the benefit of more natural color rendering that can help improve safety and security. With a color rendering index (CRI) of 75, the LUXEON Rebel demonstration lamp discussed in this paper makes it easier for drivers and pedestrians to see street signs and other objects in the area illuminated by the fixture. To the extent that people feel safer and accidents can be prevented, the importance of the quality of light cannot be underestimated

The availability of cool, neutral and warm white LEDs add the option to adjust the color temperature to the specific street lighting application. A neighborhood sidewalk might require a warmer color temperature, while a cooler LED might be used for roadway lighting to maximize efficiency. These alternatives are not available with conventional lighting technologies.

Conclusion

Taken together, these various solid state capabilities provide a persuasive value proposition for power LEDs in street lighting. As shown here, LED street lamps can meet standard regulations for luminance level and uniformity, deliver significant energy savings, dramatically extend fixture lifetime, produce more usable light, support municipalities' efforts to go green, lower the total of ownership, and more.

Clearly, with so many incentives on the table, street lighting is a logical application for today's increasingly powerful LEDs. The technology can help relieve government's ever-present budgetary and environmental challenges as well as improve street light quality through features like reduced glare and better color rendering. LEDs have come of age for traffic signals, automotive lighting and a host of other products. They now deserve serious consideration for roadway and pedestrian lighting.

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