SSL EVALUATION:

# Exterior Lighting at Princeton University

## An Ivy League institution with a comprehensive sustainability plan has been saving energy with LED lighting in multiple projects since 2008.

As a key feature of its sustainability plan, Princeton has committed to reducing its greenhouse gas emissions to 1990 levels by 2020. *Photo: Princeton University, Office of Communications.*

Chartered in 1746, Princeton is the fourth-oldest college in the United States. In 2008, the venerable institution adopted a comprehensive sustainability plan. Realizing that lighting offered considerable scope for reducing energy use and carbon emissions, and recognizing solid-state lighting's potential, the school installed its first LED exterior lighting system that same year, hoping to learn more about the technology and further its development. From that small initial step, Princeton then began similar LED lamp replacement projects in a number of interior spaces before committing to more-extensive exterior applications. The GATEWAY report *Exterior LED Lighting Projects at Princeton University* focuses on four exterior SSL projects that have been completed at Princeton since 2008.


Sequence of Princeton exterior SSL projects, with dates indicating the year in which each project was completed.

## Pedestrian Lighting on Elm Drive

In 2008, Princeton completed its first LED exterior lighting project: replacing seven high-pressure sodium (HPS) luminaires with LED luminaires along a pedestrian walkway that runs alongside a major campus roadway and connects perimeter parking areas with the central campus and several athletic fields. The upgrade reduced the wattage and energy use by more than 60%, saving about 2500 kWh annually. What's more, the school's facilities group received anecdotal reports that more students were now using the walkway because it felt safer than before.

This early project allowed Princeton to test the new LED technology in a small-scale, real-world installation. From it, the school learned that substantial energy savings without compromising light levels are possible with LED luminaires, and that the improved optical performance compared to HPS enabled better light distribution. The installation also posed a number of implementation challenges that proved instructive. For example, 480V LED drivers to match the school's 480V electrical distribution system were not available in 2008, so a transformer was added at each luminaire—although drivers designed for 480V operation have since become available and have been used in subsequent installations. In addition, several of the LED luminaires on Elm Drive experienced early failure due to electrical surges, whereas surge suppression is now integral in the LED luminaires used at the school.

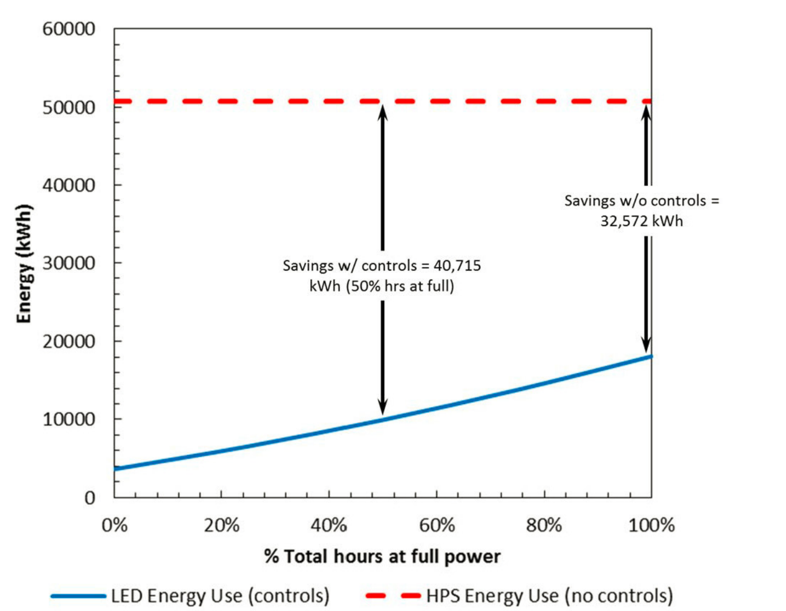
New LED luminaires along Elm Drive (left), and a close-up view (right). *Photo: Pacific Northwest National Laboratory.*

## Parking-Lot Lighting, Phase 1

Princeton's initial parking-lot project, which was completed in mid-2012, replaced 68 HPS luminaires with LED luminaires in four adjacent lots on the southwest corner of the campus. In addition to the standard dusk-to-dawn control that keeps the luminaires turned off during daylight hours, each LED luminaire also has an integral passive infrared motion detector and dims to 20% when no motion is detected. The project resulted in 64% energy savings from the reduced wattage of the LED luminaires, with further savings from the bi-level control based on motion detection.

This project broadened Princeton's experience with LED technology. Among other things, it showed that overall energy savings are greatly increased through the use of motion-based dimming, especially for parking lots with little activity during long periods, such as nighttime operating hours.

It also alleviated prior concerns that dimmed light levels might be inadequate for people approaching the lot. And it led Princeton facility engineers to look for ways to network their parking-area lighting systems into zones rather than depending on individual control, as was the case in this project—even though no complaints related to this functionality were received.

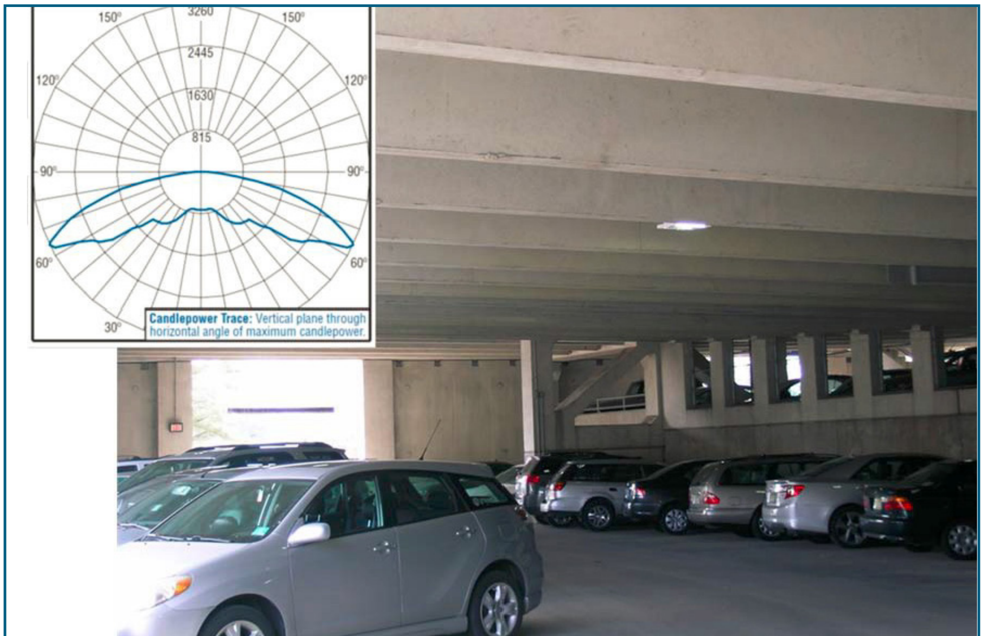



Impact of bi-level dimming controls for Phase 1 parking-lot lights. The right vertical axis illustrates the energy performance of the system when all luminaires are continuously operating at 100% power. The blue curve shows the energy use for the LED system at various assumed reductions in time spent at full power use. Energy savings are indicated for the 100% condition (100% of the time at full power) and for the 50% condition (50% of the time at full power and 50% of the time at 20% power).

## West Parking Garage

The incumbent lighting in Princeton's West Parking Garage combined 252 metal halide (MH) luminaires that operated after dark with fluorescent luminaires that operated during daylight hours. In early 2013, the MH luminaires were replaced one-for-one with LED luminaires that provided lighting both during the day and at night. Since a new system often initially provides more light than is needed, the output of the LED luminaires was set to 90% of the maximum, with the idea that this could be increased over time as the light output depreciates. The LED system saves more than 143,000 kWh annually from the reduction in power during nighttime operation alone—a 66% savings compared to the MH system—with additional savings achieved through the use of controls. Each LED luminaire has an integral motion detector and daylight sensor, with output dimmed to 50% of maximum whenever daylight is present and to 20% of maximum when there is no movement nearby. The additional savings at night from these controls is estimated at 40,000 kWh annually.

This project showed Princeton that the inherent controllability of LEDs provides opportunities for multiple levels of control during daytime and nighttime hours, allowing an LED system to replace two different incumbent systems that served the application's needs at




LED parking-lot luminaire with widespread distribution (NEMA Type V Medium).
*Photo: Pacific Northwest National Laboratory.*

different times. Mounting the LED luminaires between the concrete beams helps reduce glare for approaching drivers, but the beams can interfere with the motion detectors, so there is a tradeoff.

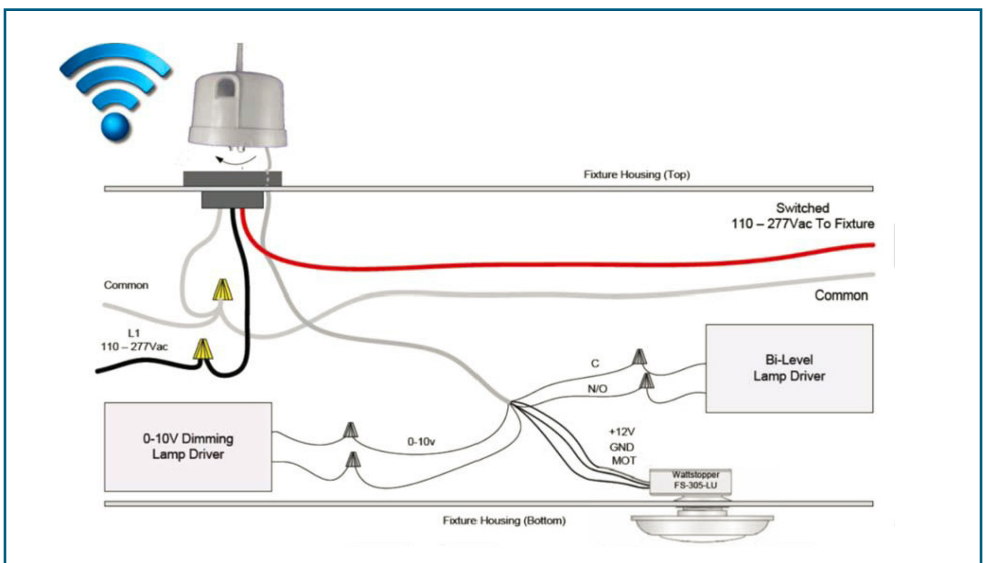
## Parking-Lot Lighting, Phase 2

Early in 2014, 41 new LED luminaires were installed in two Princeton parking lots as part of a major renovation to those areas. Because this was a new installation, the LED luminaires did not replace existing HPS luminaires, but saved more than 60% of the energy that would have been used by a conventional HPS system, with additional savings achieved through the use of controls. Each LED luminaire has an integral photocontrol and motion detector, but rather than individual control, the luminaires are grouped into zones using a wireless network. This grouping allows an area of the parking lot to dim to 20% whenever no motion is detected within that area, but brings the luminaires to full output whenever motion is detected by any one of the sensors in that zone. This effect can increase the perceived safety in the parking lot, compared to having controls on the individual luminaires, where an area adjacent to a person who is entering his or her car may remain dim.

The wireless network control also enabled Princeton to implement a programmed weekly schedule and to override the motion-detection system when desired. However, implementing the type of irregular scheduling needed for system overrides during special events must be performed manually, as the system software available at the time of installation did not allow for this functionality. Princeton is working with the vendors involved to make this functionality easier to implement in the future.

## Conclusions

From several small, early projects to larger-scale, full-building implementations, Princeton's facilities engineering staff has grown its internal knowledge base and adapted its lighting-energy approach as SSL technology continues to mature and improve. From both an economic and a carbon-reduction standpoint, the SSL experiences at Princeton have been highly successful and informative. By incorporating different types of controls into its early projects, Princeton gained valuable experience in extending the energy savings made possible by SSL efficiency. For the four exterior SSL projects described in the GATEWAY report, the expected annual energy savings just from the reduced power totals 195,443




Wireless control module schematic. *Credit: Echelon Corporation.*

| Estimated Energy Use and Savings of Princeton's Early SSL Projects | | | | | | |
|---|---|---|---|---|---|---|
| | Comparison HID System | | New LED System | | | |
| No. of Luminaires | Power (W) | Annual Energy Use (kWh) | Power (W) | Annual Energy Use (kWh–w/o controls) | Annual Energy Savings (kWh) w/o controls | Annual Energy Savings (kWh) w/controls |
| **Elm Drive Pedestrian Path** | | | | | | |
| 7 | 135 | 4,067 | 53 | 1,597 | 2,470 | 2,470 |
| **Phase 1 Parking Lots** | | | | | | |
| 48 | 189 | 39,046 | 68 | 14,048 | 24,997 | 39,810 |
| 20 | 135 | 11,621 | 47 | 4,046 | 7,575 | |
| **West Parking Garage** | | | | | | |
| 252 | 200 | 216,922 | 68 | 73,753 | 143,168 | 183,731 |
| **Phase 2 Parking Lots** | | | | | | |
| 12 | 189 | 9,761 | 68 | 3,512 | 6,249 | 20,984 |
| 29 | 135 | 16,850 | 47 | 5,866 | 10,984 | |
| **Totals** | | 298,267 | | 102,822 | 195,443 | 246,995 |

kWh, but DOE estimates that with the controls solutions that were implemented, these annual savings actually could increase to 246,995 kWh.

Through these initial projects, the school's facilities engineering staff has learned important lessons about SSL technology and has gained experience in dealing with the rapidly changing landscape of lighting manufacturers and their suppliers. These lessons and experiences continue to be applied and expanded through Princeton's ongoing commitment to SSL implementation. Several other exterior lighting projects have been completed since those covered in this report. Additionally, a number of small and large interior SSL projects have been completed at Princeton or are now underway—including replacing a compact-fluorescent system with LEDs in the Dillon Gymnasium (see separate article and video), and a major LED retrofit at the Carl Icahn Laboratory (the subject of a future report).

**Final reports on GATEWAY outdoor demonstration projects are available for download at http://energy.gov/eere/ssl/gateway-demonstration-outdoor-projects, and information about GATEWAY Demonstration University Projects can be found at http://energy.gov/eere/ssl/gateway-demonstration-university-projects.**



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