Application Considerations for LED Site Lighting Projects Using the CBEA Performance Specification: A Review of DOE GATEWAY Demonstration Projects

Photo credit: BetaLED

This parking lot showcases an installation in Manchester, New Hampshire. The site converted existing high-pressure sodium luminaires to bilevel light-emitting diode luminaires controlled via occupancy sensors and time clock. Energy savings are expected to be greater than 60 percent by installing the new system.

Performance Specifications

Light-emitting diode (LED) technology can deliver significant energy savings and high-quality lighting in commercial parking lots, especially when paired with controls. However, there are a number of considerations commercial building owners need to keep in mind to take full advantage of LED capabilities. In 2009, the Commercial Building Energy Alliance (CBEA) completed a site (parking lot) lighting performance specification designed to support effective application of LEDs based on the latest understanding of the technology. The CBEA Site Lighting Performance Specification incorporated input from numerous CBEA member companies representing the retail, commercial real estate, and hospital sectors, as well as LED manufacturers.

Since its release, the CBEA Site Lighting Performance Specification has been applied by CBEA members as the basis for several LED parking lot applications, including some U.S. Department of Energy (DOE) GATEWAY demonstration projects. Because every site and business are different, the issues and experiences (good or bad) from the application of any specification will vary. Summarizing and comparing the resulting characteristics of different real-world applications can help show the benefits and caveats of an LED application. This document provides this type of summary for the available DOE GATEWAY demonstration projects completed to date and offers some rational application results and guidance for planning an LED application.

Commercal Building Energy Alliance (CBEA)

DOE's Commercial Building Energy Alliances are driven and managed by key industry partners whose goal is to transform the energy efficiency of commercial buildings.

REA—Retailer Energy Alliance

HEA—Hospital Energy Alliance

CREEA—Commercial Real Estate Energy Alliance

Energy Savings

Energy savings from an individual project will depend on many factors besides the lighting technology itself. Separating the various energy-saving factors on a project to appropriately account for and apply them is difficult and poses a significant challenge when trying to measure and report results. These factors can include:

- *Lighting technology product efficacy*—The higher efficacy of one lighting technology over another is the large driver of energy-related lighting retrofits.
- *Effective design*—Design and placement of luminaires can affect overall savings potential and are often considered part of the effectiveness of a new technology such as LEDs.

- *Changes in illuminance*—Reducing (or increasing) illuminance (light levels) directly affects energy differences that are not directly tied to improvements in technology efficacy.
- *Control applications*—Adding controls to a project is typically considered a separate energy-saving effect from that of the technology efficacy itself. However, in some cases, the nature of a new lighting technology can make the use of controls possible where they were not before, providing at least some tie to the change to a new technology.
- *Operational changes*—When retrofits are performed, operations may also be changed to take advantage of new technology capabilities or simply because it is a good opportunity to make changes for energy savings. Typically, energy savings from these changes are addressed separately from technology changes.

Not all projects will include all of these elements, but most will encompass two or more.

- In the Walmart project, energy savings for the LED installation were reported to be 38 percent of electricity use relative to the 400 W system and 57 percent relative to the standard 1,000 W system. However, the illuminance of the LED system was lower than for the 1,000 W system.
- The Raley's grocery store parking area project produced an average 70 percent energy savings over the existing installation. However, some of these savings are attributed to the bilevel motion sensor controls applied to each pole with the LED technology. The difference in the luminaire efficacy between the LED and existing high-intensity discharge (HID) technology was 57 percent, which relates to the direct technology replacement savings. Because the average light levels were very similar between the two technologies (within 5 percent), no significant portion of the savings is attributed to light-level changes only.

This project is supported by:

- **Retailer Energy Alliance (REA)**
  commercialbuildings.energy.gov/retailer
- **Commercial Real Estate Energy Alliance (CREEA)**
  commercialbuildings.energy.gov/real_estate
- **Hospital Energy Alliance (HEA)**
  commercialbuildings.energy.gov/hospital

- The T.J.Maxx project reported a total 58 percent savings, but the project also included a 47 percent reduction in average illuminance and the application of motion sensors. These changes could account for most of the savings.

Illuminance Reduction

In many lighting energy projects, a reduction in energy is accompanied by a reduction in illuminance. In some cases, this is the unintended result of an inadvertent characteristic of the technology chosen and/or its application. In other cases, this may be part of the strategy where spaces are found to be overlighted. For example, the delamping of 2-foot by 4-foot fluorescent luminaires is historically a common energy retrofit that may be driven by the realization or perception that spaces are overlighted or that a reduction in illuminance is an acceptable change. However, delamping like this is not always considered a quality energy option because of the potential for lack of uniformity or desired light level. In still other cases, a technology change may increase lighting levels because of lamp size choices, for example. However, for LED technology in particular, this will definitely increase initial costs and may not be appropriate for the application. For this reason, most LED retrofit projects focus on providing the right amount of light to minimize initial costs while providing appropriate lighting.

- In the Walmart project, illuminance was reduced by approximately one-half to three-quarters of the original 1,000 W metal halide (MH) design levels, bringing the illuminance closer to the standard Illuminating Engineering Society (IES) recommendations in IES-RP-20. Although this approach saves both energy and cost, Walmart management has expressed concern about replicating the lower illuminance at other sites because of perceived brightness. Lighting perception is affected by ambient conditions, and parking lots in more densely populated areas with more surrounding light may appear dim by comparison. In addition, darker parking surfaces such as asphalt can reduce reflected light, which could also produce dimmer appearances.
- The Raley's grocery store parking project encompassed replacement LED luminaires with motion sensors to reduce energy (and illuminance) by approximately 30 percent during low occupancy periods. The illuminance at full power is just slightly higher (1.9 foot-candles [fc]) than the previous MH levels, which are approximately 1.8 average fc. The designed low-level setting of the LED luminaires that is triggered by the occupancy sensor is approximately half of this at 0.9 fc. All of these levels (new and old technology) are above the IES recommendations for parking lots (0.2 fc) but are also typically lower than the levels in many existing parking areas, which typically are overlighted by up to several times the recommended levels.

- The T.J.Maxx project measurements show that in portions of two areas of the LED installation (front aisle and main parking), the system did not meet the CBEA specification in terms of minimum illuminance and uniformity (though neither did the original pulse start metal halide [PMH] system). This was mostly due to the shape of the parking lot rather than deficiencies of either lighting system, and these minimums do not necessarily represent any significant lack of effective illumination. The minimum illuminance could have been met by adding a luminaire, though this would also slightly decrease the energy savings as well as payback. Based on feedback, however, the LED system was considered a success.

Cost Effectiveness

The economics of any lighting project is important for evaluating the viability of a project. This can range from simple budget fit to more involved tax credit and utility rebate determinations. For LED projects, this is particularly critical because of the current high cost of LED products and potential for long lifetimes affecting maintenance costs. There are many elements to the cost of a project, including:

- Luminaires (lamps, drivers, housing)
- Poles or other mounting hardware and associated rewiring (if any)
- Maintenance
- Demolition of existing equipment or structure
- Design services (if needed).

Every project will have a variety of costs, and the determination of which costs to include can depend on a variety of organizational or business needs. The costs identified and quantified in these demonstrations are examples of the types of items to be considered:

- In the Walmart project, the simple payback for the LED installation was 7.5 years when considered against the standard 1,000 W PMH system and 6.1 years when compared to an alternative 400 W PMH system. This may be a longer payback than many retailers prefer but was driven in part by the location's relatively low electricity and labor costs. The LED system elements with the most influence on payback were the additional luminaires and poles needed to light the site. The initial cost of the LED luminaires can be expected to continue to decrease. Over the 10-year analysis period, the LED system is expected to achieve the lowest life-cycle cost of the three systems considered, but this depends on the expected long life of the LED system.
- The Raley's grocery store project simple paybacks were 3.3 and 4.7 years for new construction and retrofit scenarios, respectively. The corresponding 15-year net present values were approximately $2,660 and $2,290. Due to the robust nature of LED technology and uncertainty regarding the useful life of the luminaires, the Raley's economic analysis assumed the LED luminaires have near-zero regular maintenance cost during their useful life. When maintenance and replacement costs for MH luminaires were combined with energy costs, the bilevel operation LED luminaires cost approximately $278 less per year to operate than an MH luminaire. Economic performance in this demonstration was sensitive to maintenance savings, as these were the primary contributor to a favorable payback. Since individual sites will have different characteristics from those described here, readers are strongly encouraged to use their own savings estimates.
- The T.J.Maxx LED project achieved an estimated payback of about three years compared to the existing high-pressure sodium installation. This lower payback is believed to be partially an effect of the previous system's high maintenance and energy costs, which were caused by issues with poor power quality that reduced lamp life and drove a significant portion of the previous maintenance cost. Equipment to improve power quality was installed simultaneously with the new LED luminaires; therefore, maintenance costs presumably would have decreased even if the old luminaires had been retained. Using the national average electric rate and lower maintenance costs associated with more typical power quality, a payback of up to five years might result if the project were located elsewhere.

DOE Support

DOE provides technical assistance in support of this specification project, including:

- **Product performance testing**
- **Product demonstration technical support**
- **Analysis of energy cost savings**
- **Analysis/quantification of maintenance cost savings**
- **Investigations into life measurements and other performance indicators**
- **Development and maintenance of the CBEA product performance specification**
- **Technology specification technical assistance**

Customer/Business Satisfaction

Important to the success of any project is ensuring that the results are acceptable to the customers/occupants and to the building operations staff. Occupant dissatisfaction is generally unacceptable to building and business owners. Therefore, understanding occupant perception and level of acceptance of any new technology that could be perceived as untried or risky is important. Although determining satisfaction among a variety of occupants is difficult, surveys of large enough groups can

be instructive, and properly administrated survey instruments can get usable results and identify major issues, which hopefully can be addressed.

Building operators must be convinced that the project can be effectively and consistently operated and maintained. This can be most effectively accomplished by involving the building operators at the start of the project. Building or business senior management also needs to be satisfied with the capabilities and appearance of the installation for it to be considered successful and therefore applicable to other sites. Surveys were completed for several of the demonstration projects, with varying results.

- Walmart conducted exit interviews on a diverse group (varying in age, gender, ethnicity, shopping alone and/or with others) of more than 40 customers after nightfall outside their Leavenworth, Kansas, location and another store in Peoria, Illinois. The store in Peoria was lighted by traditional MH luminaires and was determined to serve a similar population base as the Leavenworth site. When prompted, customers provided positive feedback about both lighting systems. Although Walmart management has expressed concern about replicating the lower illuminance at other sites where the lots may appear dimmer than surrounding businesses, there was no indication that customers at this location perceived the parking lot as dim, unsafe, or otherwise insufficiently illuminated.
- A Raley's survey of 17 employees working in the West Sacramento, California, store resulted in positive feedback from store employees, who felt the new lighting provided more light and improved the appearance of the parking lot. Overall, employees were satisfied with the new lighting, with 16 of 17 responses rated 7 or higher on a 10-point scale (with 10 being "highly satisfied"). The survey responses also indicated that 16 of 17 employees would recommend that Raley's consider this type of lighting at other locations. Employees also indicated that they felt safer with the new lighting. Only two employees indicated that they had received feedback from store customers about the change in parking lot lighting. In both cases, the customer feedback was positive, indicating that the parking lot looked brighter and felt safer.
- The T.J.Maxx project reported that 30 out of 32 store employees surveyed would recommend this installation be used at other locations. Most thought that lighting quality was improved following the LED substitution. All respondents indicated that the new installation was equivalent to or better than the existing installation. Only one respondent did not think this type of lighting should be used at other locations, though no further explanation was provided. One employee commented that new lighting "shows stores are open."

Safety/Security

Safety and security are on the minds and charters of most organizations to protect customers and employees and avoid potential litigation. Lighting is typically an integral part of the plans and protocols for safety and security but is often only considered in terms of "more is better." IES offers specific guidance on lighting for safety and security (G-1), and the keys to its effectiveness include multiple elements such as illuminance, uniformity, and color. Energy-efficient lighting may not meet some organizational safety or security lighting requirements that are based primarily on high levels of lighting. Therefore, building staff and departments responsible for safety should be involved early in the project planning. Other business departments such as marketing, customer service, and human resources should also be consulted, as the revised lighting can pertain to customer and employee relations and satisfaction.

Safety and security were addressed in the various demonstration projects, mostly in reference to light levels related to standard or enhanced levels recommended by IES (see Illuminance Reduction section). Some survey comments related to security in all of the projects indicated an "increased sense of security with the LED lights."

Further guidance to support energy-efficient lighting is offered in a document prepared for CBEA members at www.pnl.gov/main/publications/external/technical_reports/PNNL-18173.pdf.