Customer Advanced Technologies Program
Technology Evaluation Report

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About the Customer Advanced Technologies Program

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems and a wide variety of other technologies.

For more program information, please visit: http://www.smud.org/education-safety/cat.html.

Executive Summary

For the past few years, SMUD has conducted several research projects to explore the potential benefits of LED lighting for a variety of applications including interior replacement lamps, street lighting, parking lots, gas station canopies and commercial parking structures. Objectives for these projects included assessing the lighting performance, energy and cost savings potential. The results were used in developing commercial rebate programs for LED lighting technologies for 2010.

SMUD partnered with the California Lighting Technology Center (CLTC), California State University Sacramento (CSUS), the City of Sacramento and BetaLED to test bi-level LED lighting systems in commercial parking structures. The first project was a proof-of-concept effort at CSUS in 2007. The second project with the City of Sacramento occurred in 2009 and included a fully commercialized version of the fixtures used at CSUS. Results included:

- ✓ Higher initial illumination levels
- ✓ Improved lighting quality
- ✓ Energy savings of 37% to 67%
- ✓ Simple financial paybacks of 10 to 15 years (energy savings only)

Although the simple financial paybacks for these projects were indeed long, the cost savings were based upon a utility rate of $0.10 per kWh - many customers pay considerably higher rates. Also steady improvements in LED technology and increased competition between manufacturers should help bring down costs in the near future.

Introduction

It‘s 2:00 a.m. All is quiet in the parking garage except for the steady hum of the high-pressure sodium light fixtures. These guardians of public safety burn brightly 24 hours per day, 365 days per year. Which begs the question – why?

This scenario plays out in many parking structures all across the nation. Although high pressure sodium and metal halide fixtures are energy efficient, they are not well suited for dimming and other control strategies. Consequently, property owners are very reluctant to use motion sensors. The result is a lot of wasted energy. Fortunately, there is a new high tech option available: bi-level LED fixtures with motion sensor controls.

In 2007, SMUD partnered with the California Lighting Technology Center (CLTC), California State University Sacramento (CSUS) and BetaLED to develop and test a proof-of-concept LED fixture. The idea was to replace the existing high pressure sodium fixtures with bi-level LED fixtures that would switch the LEDs into low mode during periods when no one was around. Two years later, the City of Sacramento agreed to test a fully commercialized version of the same fixtures used at CSUS. The results of these two projects are presented on the following pages of this report. SMUD wishes to acknowledge and thank CSUS and the City of Sacramento for their pioneering spirit and willingness to test new technologies.

Showcase Project

Project Location: California State University Sacramento (CSUS)
Parking Structure 1
Sacramento, CA 95819

Parking Structure Information

- Built in 1992
- Five levels with a total of 494,208 sq. ft.
- Floor to ceiling height: 9 ft. 6 in.
- Floor to bottom of beams: 7 ft.
- Existing: three hundred and fifteen150-Watt HPS fixtures (measured at 189 Watts per fixture)
- Most fixtures on 8,760 hours per year (some fixtures controlled via photocells)
- Test area: one section of the third floor plus one of the student entrances to the garage
- 32 LED fixtures installed, 25 monitored

Figure 1: photos of the CSUS parking garage before and after the LED retrofit.

Proto-type LED Fixture

- Proof-of-concept fixture with passive infrared sensor (BetaLED; The WattStopper® Inc.)
- Three light bars (60 Gen A LEDs)
- Type V distribution
- CCT: 6000K
- CRI: 70 CRI
- Low mode
  - 77 Watts (measured)
  - 5100 lumens (per BetaLED)
- High mode
  - 165 Watts (measured)
  - 7905 lumens (per BetaLED)

Figure 2: prototype bi-level LED fixture.

Summary of Results

- 36% energy savings
- Positive feedback from Campus Police and students
- Fixtures produce a lot of glare if viewed directly while walking, yet seem to be ok when driving.
- Financial summary
  - Cost for 25 fixtures: $22,497 (self installed)
  - Estimated utility bill reduction: $1,460
  - Simple payback: 15.4 years (@ $0.10 per kWh)

Lessons Learned

- At least 25% more savings could have been achieved if the wattage for the low mode had been reduced.
- Traffic patterns of the cars and pedestrians within the parking structure have a dramatic impact upon the amount of savings.
- Reliability so far has been excellent. According to Mr. Nat Martin, Energy Conservation Coordinator for CSUS, only three of 1,920 LEDs (0.001%) have failed after more than two years of 24/7 operation.
- Illumination levels were much more uniform with the LED system (see Figure 3 below).

Customer Feedback

"First, I need to say this was a risky project, but thanks to the help of SMUD and the folks at the California Lighting Technology Center (CLTC), it was worth the risk. Dave and I met with CLTC, BetaLED and Watt Stopper to talk about what I would need to take this risk. We discussed several fixture options and how BetaLED would connect the occupancy sensor to the LED fixture. Since this had never been done before, there were a lot of issues that needed to be worked out. Once the wattages and lighting levels were agreed on, we decided how many fixtures would be needed for a reasonable test and where best to locate them in the parking structure.

This project was a success, and only one of several I have had the pleasure of working with SMUD."

Nathaniel C. Martin, CEM
Energy Conservation Coordinator
California State University, Sacramento

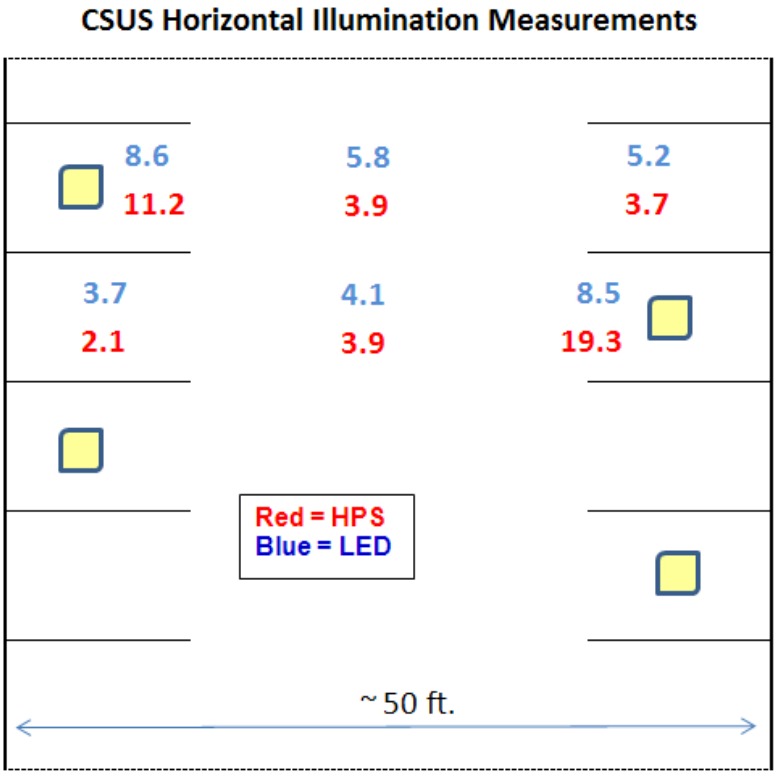

Figure 3: these illuminance measurements were taken using a calibrated light meter. Since this site used very few fixtures, uniformity was a challenge.

Showcase Project

Project Location: City of Sacramento Parking Garage
414 J Street
Sacramento, CA 95814

Parking Structure Information

- Built in 1990
- Two levels with a total of 180,000 sq. ft.
- Floor to ceiling height: 9 ft.
- Floor to bottom of beams: 7 ft. 5 in.
- Baseline lighting system: two hundred and seventy two 175-Watt, metal halide and mercury vapor fixtures
- Fixtures on 8,760 hours per year
- Test area: a section of the basement level
- Total of 25 LED fixtures (all were monitored)

Figure 4: photos of the Sacramento City parking garage after the LED retrofit.

LED Fixture Information

- Commercialized version of CSUS fixture (BetaLED)
- Integrated passive infrared sensor
- Three light bars (60 Gen B LEDs)
- Type V distribution
- CCT: 6000K
- CRI: 70 CRI (per BetaLED)
- Low mode (175 mA)
  - 39.5 Watts (per BetaLED)
  - 3,060 lumens (per BetaLED)
- High mode (525 mA)
  - 118.5 Watts (per BetaLED)
  - 6,630 lumens (per BetaLED)

Figure 5: the LED fixtures at the City parking garage included integrated motion sensors similar to this one.

Summary of Results

- 66.7% energy savings
- Higher illumination levels
- Positive feedback from electricians and executive management
- Fixtures still produce glare if viewed directly while walking, yet seem to be ok when driving.
- Financial summary
  - Cost of 25 fixtures: $24,244 (self-installed)
  - Estimated annual utility bill reduction: $2,481
  - Simple payback: 9.8 years (@ $0.10 per kWh)

Lessons Learned

- Although this project resulted in excellent savings (67%) even more savings could have been achieved if our confidence in the illumination levels produced by the LED fixtures would have been higher. In the high mode, the LED fixtures produced twice as much light as the original system (see Figure 6 below).

- Since the lighting for these facilities are usually designed to exceed minimum recommended illumination levels, significant savings opportunities exist – especially for bi-level fixtures (see Figure 7 on page 6).

- Acceptable maximum to minimum illumination ratios were easily attained replacing fixtures on a one-to-one basis.

- Vertical illumination levels were significantly increased.

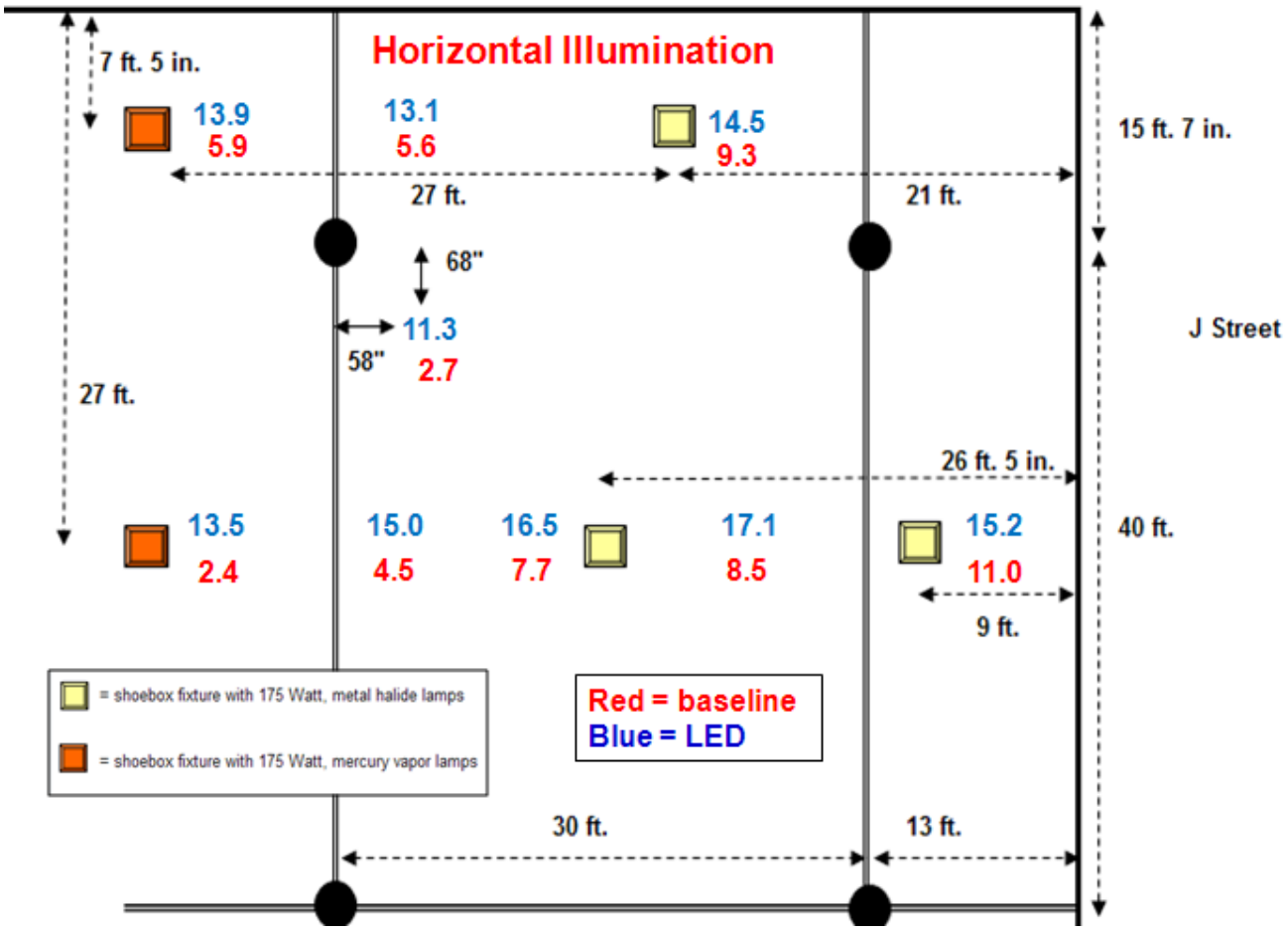

Figure 6: The project team used a calibrated light meter to measure horizontal and vertical illumination levels before and after the retrofit. Overall, the new LED fixtures produced excellent results including higher initial illumination levels, less glare, and less light pollution.

The energy consumption of the original metal halide and new LED lighting systems was monitored by ADM Associates Inc. As shown in Figure 7, using bi-level LED fixtures in commercial parking structures may present an excellent savings opportunity.

The savings for this project were much higher than the CSUS project for two reasons. First – the fixture wattage in the low mode was much lower (39.5 Watts versus 77 Watts). Secondly, the traffic patterns at the City garage were more favorable for this control strategy. At the CSUS site, all of the parking spaces are adjacent to the ramps. In other words, cars traveling from one level of the garage to another level pass by all of the lights and activate the sensors.

Figure 8 shows the average load profile for the 25 LED fixtures at the City garage. The total wattage for all 25 fixtures in the high mode would be 2.9 kW, yet the highest recorded demand was about 2.4 kW. This means that at no time were all 25 fixtures operating in the high mode. This is especially interesting considering the fact that all of the fixtures are in the same area of the garage.

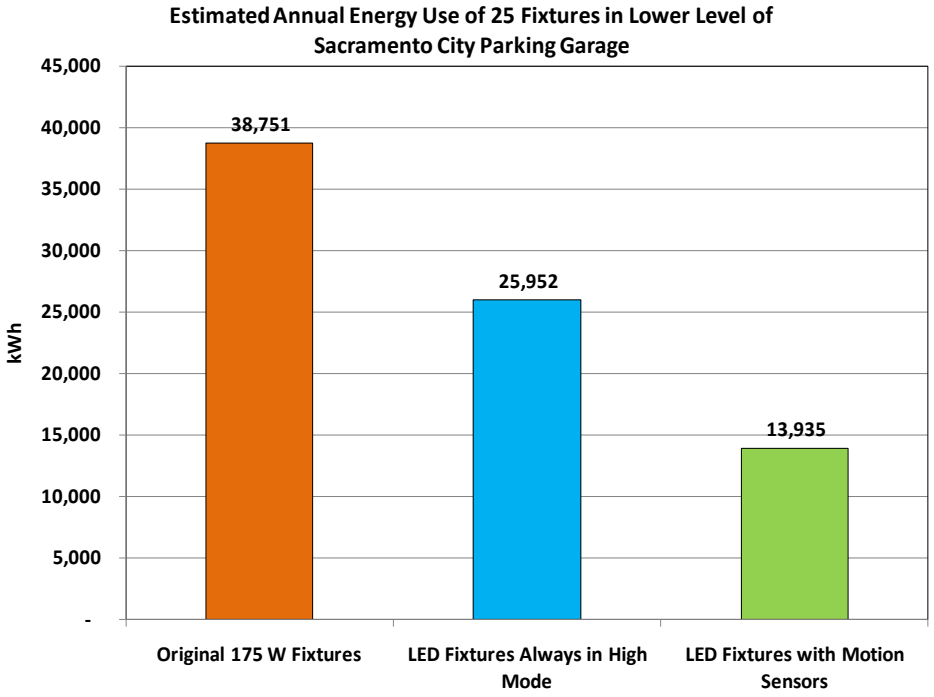

Figure 7: energy consumption of the original metal halide and new LED lighting systems.

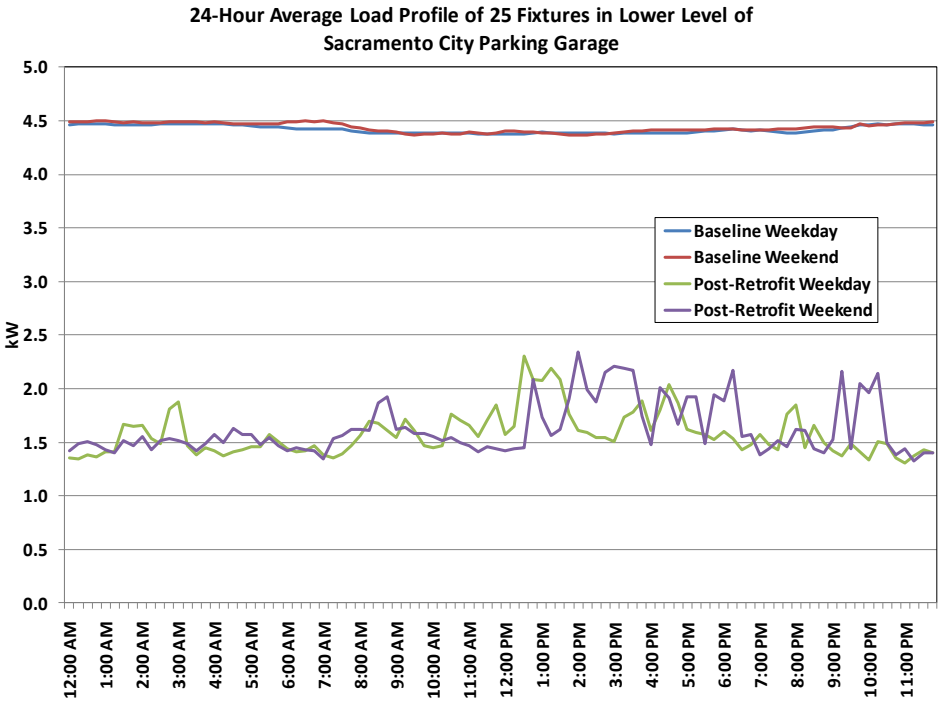

Figure 8: Typical daily load profile of the LED lighting fixtures.

Customer Feedback

"The LED light fixtures are performing above expectations. The excellent color rendering capabilities, combined with the white light produced by the LED fixtures, help to create a more pleasing environment. The high-low light level controls work very well. Even in the low mode there is adequate light in the space. As mentioned elsewhere in this report, if we knew the light fixtures were going to perform so well, and produce so much light, we could have used fewer LED's and saved additional energy. The City of Sacramento will continue to monitor the installation and will use the results to help determine how future light fixtures will be used to retrofit existing garages."

James Christenson, P.E.
Senior Engineer
City of Sacramento

Final Thoughts

Demonstration projects such as this one provide valuable insights for deploying emerging technologies. Lessons learned from these projects include:

- The Illumination Engineering Society of North America (IESNA) recommends a minimum illuminance level of 1 to 2 foot-candles (with the exception of the entrances). for most areas of commercial parking structures and a minimum to maximum ratio of ten to one.[1] Since high quality LED fixtures may offer very uniform illuminance, tremendous savings opportunities exist. Selecting fixtures with fewer LEDs or lower drive currents would have reduced first costs, provided more savings and improved the financial payback for these projects.

- Although laboratory testing suggests the useful life of these LED fixtures should reach 50,000 hours or more, the jury is still out. Currently, IESNA is reluctant to extrapolate beyond 35,000 hours. SMUD intends to revisit this and several other sites to track the illumination levels on a yearly basis.

- SMUD will offer energy efficiency incentives for qualified LED exterior fixtures in 2010. Although the details are still under development, the program should be up and running by February 1, 2010. Please call SMUD Commercial Services, 1-877-622-7683 or visit www.smud.org for details.

[1] The IESNA Lighting Handbook, Ninth Edition