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GATEWAY
Demonstrations

Demonstration Assessment of LED Parking Structure Lighting

Host Site: U.S. Department of Labor Headquarters, Washington, D.C.

March 2013

Prepared for:

Solid-State Lighting Program
Building Technologies Office
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Prepared by:

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Demonstration Assessment of Light-Emitting Diode Parking Structure Lighting at U.S. Department of Labor Headquarters

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March 2013

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Preface

This document reports on the evaluation of a lighting demonstration project conducted under the U.S. Department of Energy (DOE) GATEWAY Solid-State Lighting (SSL) Technology Demonstration Program (GATEWAY). The program supports demonstrations of high-performance SSL products in order to develop empirical data and experience with applications of this advanced lighting technology. The GATEWAY Program focuses on providing a source of independent, third-party data for use in decision making by lighting users and professionals; the data contained herein should be considered in combination with other information relevant to the application(s) and site(s) under examination. GATEWAY demonstrations typically compare one or more SSL products against the incumbent technology used in that location. Depending on available information and circumstances, SSL products may also be compared to alternative lighting technologies.

Products demonstrated in the GATEWAY Program are generally prescreened and/or tested to verify their actual performance. However, DOE does not endorse any commercial product or in any way guarantee that users will achieve the same results through use of these products.

Electronic copies of this report are available from DOE's SSL website at http://www1.eere.energy.gov/buildings/ssl/gatewaydemos.html.

Executive Summary

This report documents a solid-state lighting (SSL) technology demonstration at the parking structure of the U.S. Department of Labor (DOL) Headquarters in Washington, DC, in which light-emitting diode (LED) luminaires were substituted for the incumbent high-pressure sodium (HPS) luminaires and evaluated for relative light quantity and performance. The project was supported by the U.S. Department of Energy (DOE) GATEWAY Solid-State Lighting Technology Demonstration Program.

The demonstration results show energy savings of 52% from the initial conversion of HPS to the LED product. These savings were increased to 88% by using occupancy sensor controls that were ultimately set to reduce power to 10% of high state operation after a time delay of 2.5 minutes. Figure ES.1 shows the relative annual energy use per luminaire for each of the operating scenarios evaluated in this study.

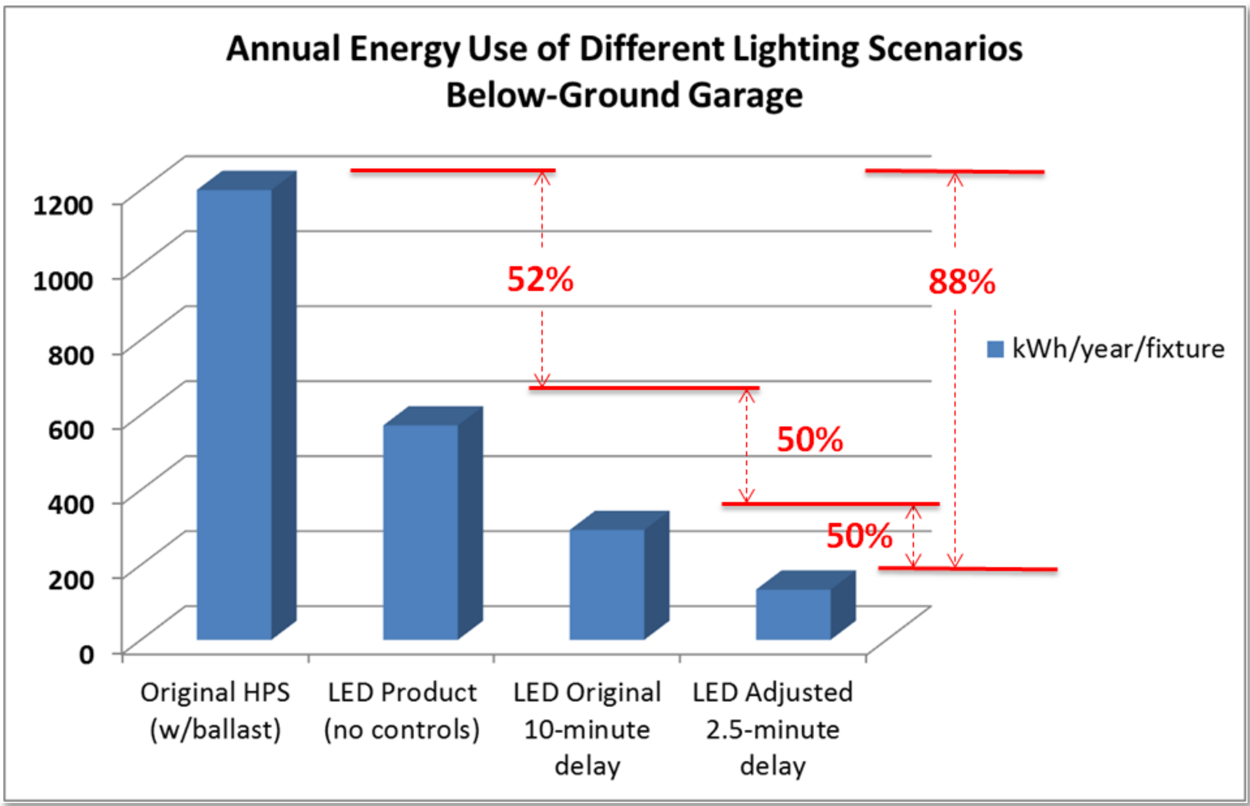

Figure ES.1 Estimated annual energy use per luminaire under each operating scenario.

The results demonstrate that the time delay setting of the occupancy sensor significantly influences the energy use of the lighting system. The delay setting need only be long enough to cover the typical period between a vehicle entering the area and parking, with perhaps a short additional period while occupants gather their things before exiting the vehicle. For this reason, the factory-default 10-minute delay setting was judged to be longer than necessary and was reduced to 2.5 minutes. Figure ES.2 shows the daily average percent operation in high state for all luminaires with the initial, factory-set time delay of 10 minutes. This data was recorded during a series of monitoring periods between April and September 2011, providing a cumulative 85 days of data. Figure ES.3 shows operation of the same luminaires after the time delay was reduced to 2.5 minutes. This data was recorded during a series of monitoring periods between December 2011 and March 2012, yielding 42 individual days of data. As shown in the figures, the operating profiles under the two time delay settings are dramatically different.

Garage use at DOL Headquarters remains fairly consistent throughout the year, suggesting that all of the additional savings are attributable to the simple adjustment of the delay timing. Furthermore, as no complaints have been received from garage users to date, these significant gains apparently come at little cost other than the brief labor to make the adjustment.

A number of the luminaires exhibited what appeared to be false-tripping behavior on several occasions. Some of this behavior could have been caused by high air flow from a nearby air handler, although this likely does not explain all such anomalies in the data. Overall, false tripping did not have a significant negative effect in the final results.

Because of the relatively high cost of the LED luminaires at their time of purchase for this project (2010), the simple payback periods were 6.5 years and 4.9 years for retrofit and new construction scenarios, respectively.

Staff at DOL Headquarters reported high satisfaction with the operation of the LED product.

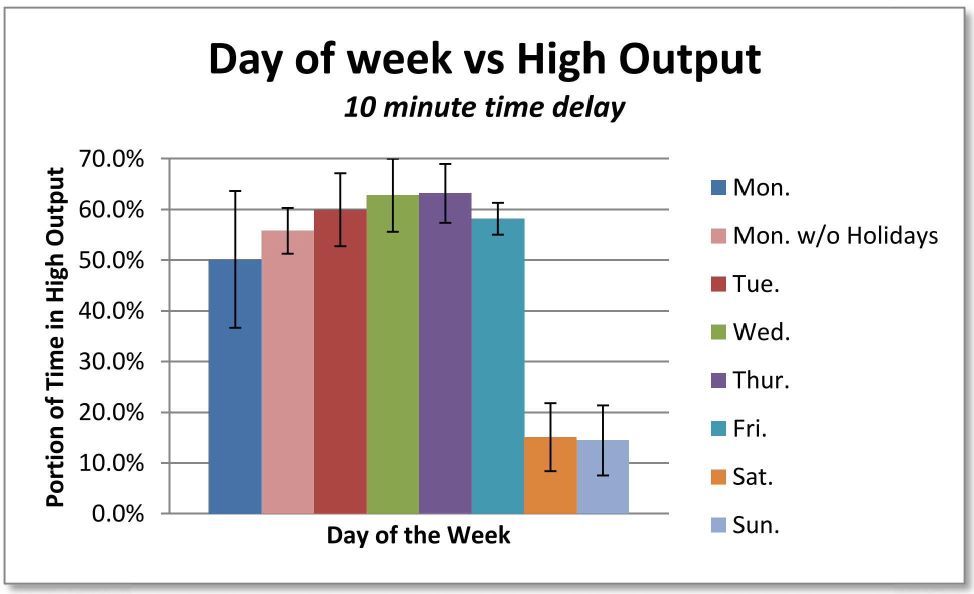

Figure ES.2. Operating Profiles of Metered Luminaires at 10-Minute Delay Setting

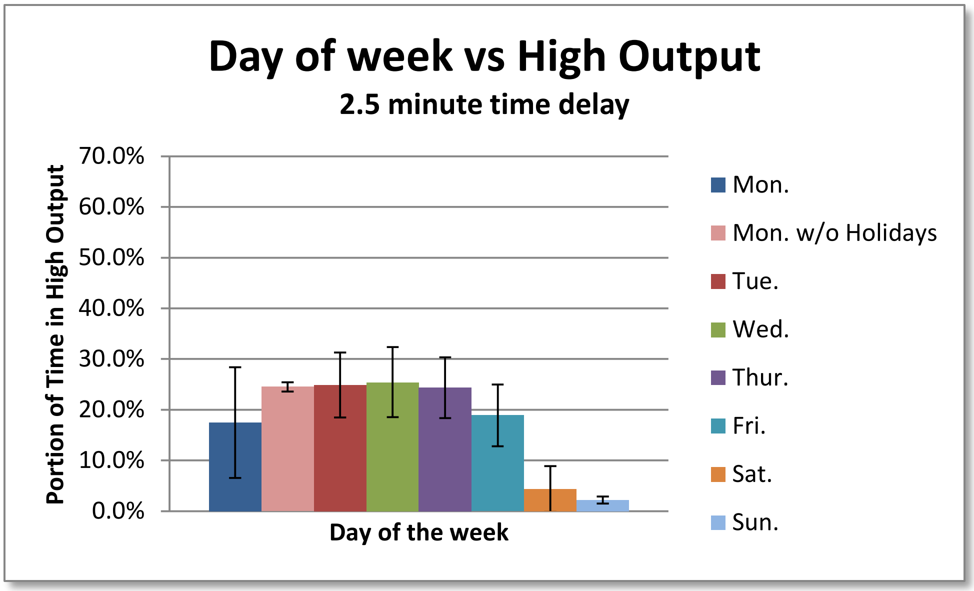

Figure ES.3. Operating Profiles of Metered Luminaires at 2.5-Minute Delay Setting

Acronyms and Abbreviations

BLS	Bureau of Labor Statistics
CV	coefficient of variation
CT	current transformer
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
fc	footcandle(s)
HPS	high-pressure sodium
IES	Illuminating Engineering Society of North America
kWh	kilowatt-hour(s)
LCC	life-cycle cost
LDD	luminaire dirt depreciation
LED	light-emitting diode
LLD	lamp lumen depreciation
LLF	light loss factor
lm/W	lumen(s) per watt
SIR	savings-to-investment ratio
SSL	solid-state lighting
Std. Dev.	standard deviation

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1.0 Introduction

In a project supported by the U.S. Department of Energy (DOE) GATEWAY Solid-State Lighting (SSL) Technology Demonstration Program, incumbent high-pressure sodium (HPS) lighting fixtures were replaced with light-emitting diode (LED) luminaires in one area of one floor in the parking garage of the U.S. Department of Labor (DOL) Frances Perkins Headquarters Building in Washington, DC, in 2010. The luminaires were monitored over approximately 1 year to evaluate their performance.

Parking garages and structures often present attractive energy savings opportunities because their lighting frequently operates 24 hours per day for safety and security, regardless of actual building use. Like many commercial office buildings, the Frances Perkins Building and its dedicated parking facilities have a fairly predictable use pattern, with most activity occurring between about 8 am to 6 pm, Monday through Friday, and much lower and more sporadic use otherwise. Activity within this parking garage is regulated by a security booth at the entrance, so there is no random use of the parking structure by other than DOL staff conducting official business. Despite the consistent use pattern, security issues require illumination in every section of the garage, 24 hours per day, 7 days per week, including holidays.

Energy efficiency is a particular focus of the DOL Headquarters facilities staff. In 2008, the building received an ENERGY STAR rating, which requires a continued reduction in energy use from year to year to maintain the rating. In addition, Labor Secretary Hilda Solis, a former House member who served on various energy-related committees, contacted the DOL Headquarters facilities staff on her first day at the building to ask how it could be made more energy efficient. Finally, all Federal agencies are required by Executive Order 13423 to reduce energy intensity by 30% (compared to 2005) by 2015 (or roughly 3% per year).

These factors, which underscore the continued emphasis on energy efficiency at DOL Headquarters, led facilities staff to contact the DOE GATEWAY Program to help identify energy savings opportunities using LED lighting in their building. The GATEWAY Program, in turn, happened to be looking for a strong demonstration opportunity near the National Mall that would be easily accessible to government visitors. DOL Headquarters was a natural fit.

During a brief visit, GATEWAY staff noted the parking garage and its attendant characteristics, and the significant energy savings opportunity presented. Potential savings were possible not only by retrofitting the existing HPS lighting with LED technology, but also by taking advantage of occupancy sensor[1] controls that would be enabled by the use of LED products and would capitalize on the lighting schedule and building use patterns. DOL facilities staff quickly agreed that significant potential existed and were more than willing to investigate. At the same time, the GATEWAY Program had just awarded a Next Generation Luminaires prize to a parking garage luminaire (Next Generation Luminaires 2013) and was interested in demonstrating it in a real world installation.

With all the pieces thus coming together, the demonstration project was established.

[1] The terms “occupancy sensors” and “motion sensors” are used interchangeably in this report.

2.0 Site Description

The Frances Perkins Building was built in the mid-1960s and comprises 1.96 million square feet of office space on six floors (façade shown in Figure 2.1). The General Services Administration turned control of the building over to DOL in the mid-1980s, making DOL one of the first agencies to gain authority over their own building.

Figure 2.1. Façade of Frances Perkins Building

2.1 Parking Garage

The Frances Perkins Building contains two subterranean parking garages. Each is a six-level parking structure with daylight available only at the entrance and exit. Traffic flows in one direction on each side of the garage, and each floor is split into two levels at slightly different elevations (Figure 2.2). Individual parking spaces are assigned. There are approximately 300 luminaires total throughout both garages.

The parking structure is a limited access, secure facility. Access is available 24 hours per day and controlled during business hours through an attendant-operated security gate and during non-business hours via a card-lock system. The building itself houses a typical office environment where employees tend to arrive between 6:00 am and 9:00 am and leave between 3:00 pm and 8:00 pm.

The floors of the structure are supported by large (3-ft diameter) columns in the space, visible in Figure 2.2.

Figure 2.2. Photo of Split Levels of Parking Structure and 3-ft Columns Supporting the Floors

2.2 Luminaires

Prior to the demonstration, the entire structure was lighted by HPS luminaires, which had previously replaced fluorescent T12s that were original to the building. This demonstration replaced 19 of the HPS luminaires one-for-one with LED luminaires in one section of a middle floor. The luminaires featured in this demonstration included the incumbent HPS luminaire from USA Architectural Lighting (Figure 2.3) and the VizorLED manufactured by Philips Wide-Lite (Figure 2.4). The LED luminaires have an integral occupancy sensor that can control their output through bi-level dimming.

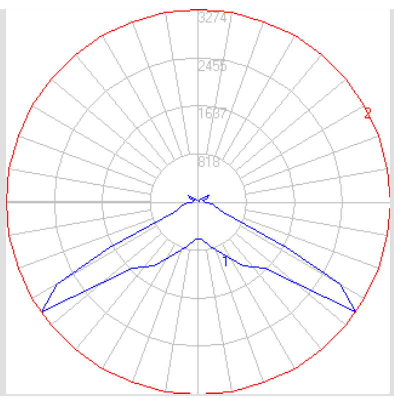
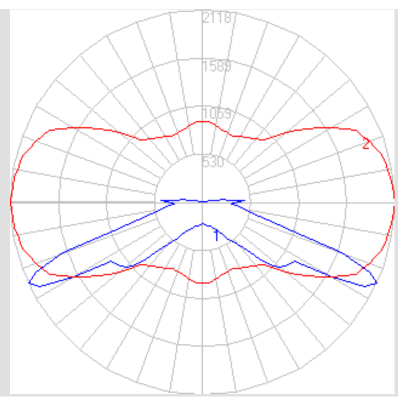
Figure 2.3. Existing HPS Luminaire

Figure 2.4. New LED Luminaire

Table 2.1 compares the existing, 100 W (nominal) rated HPS and LED luminaires. The HPS luminaire emits more light and is more efficacious than the demonstration LED luminaire and probably retains some of this comparative advantage over its expected life, even with depreciation.[1] There are three distinct differences in the photometric distributions between the HPS and LED luminaires that are critical to the performance results:

1. Output – the HPS luminaire emits more lumens and has a greater maximum intensity than the LED luminaire.
2. Horizontal distribution – the HPS luminaire has a circular (radially symmetrical), horizontal distribution whereas the LED luminaire has more of an oval or oblong distribution.
3. Vertical distribution – the angle of maximum intensity is slightly lower for the HPS luminaire, among other minor differences.

Table 2.1. Luminaire Comparison

	Existing HPS Luminaires	New LED Luminaires
Manufacturer	US Architectural Lighting	Philips Wide-Lite
Catalog number	PSL12S-V-PD-100-HPS-MT-QTZ	VZ-24-60-B-277-EZ-PZ10-ASA
Light source	HPS	LED
Number of light sources	1 lamp	60 LEDs
Rated light source	100 W	---
Luminaire lumens (initial)	7,751	4,411
Luminaire input power (watts)	130	62
Luminaire initial efficacy (lm/W)	82	65
Photometric distribution		
Maximum intensity angle	55º	65 º
Maximum intensity (cd)	3,274	2,118

Lm/w is lumens per watt; cd is candelas. See Appendix A for product cutsheets.

Another major difference in the LED luminaire is the inclusion of an integral passive infrared occupancy sensor control, whereas the HPS luminaire offers only two possible states at full output, "off" or "on." In this installation, the latter was in effect at all times for all incumbent luminaires.

In contrast, the LED luminaires contain a field-selectable, multi-level driver that allows operation in multiple output settings. The occupancy sensor is adjustable to time delays between 30 seconds and 30

[1] Since this demonstration began, Wide-Lite has released a newer version of the LED luminaire (Model VZ24-60G2-350-B-277-EZ-PX10-TSA) that still emits fewer lumens than the existing HPS but has a similar efficacy. The manufacturer specifications list the luminaire emitting 5,342 lumens at 350 milliamps with a power draw of 69 W (nominal), for an efficacy of 77 lm/W (Philips 2012).

minutes, dropping the wattage by as much as 90% from full power. In this "low" state, the luminaires draw roughly 6 W and produce approximately 450 lumens. The occupancy sensors are delivered factory-set to a 10-minute delay (i.e., the set time between the last detected movement and the luminaire returning to low state). The occupancy sensors have a detection coverage radius of about 28 ft at the 9-ft mounting height.

The contrast between high and low states of operation is clearly visible in Figure 2.5 and Figure 2.6.

Figure 2.5. Occupied Parking Space with LED Luminaire in Low State (10% Full Power)

Figure 2.6. Occupied Parking Space with LED Luminaire in High State (100% Full Power)

2.3 Installation

As noted, the HPS luminaires were replaced with the LED luminaires on a one-for-one basis. The LED products were hung from a mounting bracket and swung into place, which would normally make for quick and easy installation. In this case, however, the mounting bracket did not line up precisely with the existing junction box, so new holes had to be drilled, slightly increasing the installation time.

Installation also included some commissioning of the occupancy sensors and LED drivers, a typical requirement of control systems regardless of light source. The design of this particular product relies on a single button, which had to be pressed up to 17 times in a given sequence to set the time delay and luminaire output.

Figure 2.7 shows the parking structure layout and luminaire locations. The arrows indicate the direction of vehicle travel in the space. The right-hand side of the drawing (largely blank) corresponds to the higher split level visible in Figure 2.2, where the HPS luminaires remained unchanged. In the left-hand side of the figure, the new LED luminaires are depicted as small rectangles. The dashed circles surrounding the LEDs represent the area of coverage of the integral occupancy sensors. The small, darker circles represent the columns in the space. Figure 2.8 and Figure 2.9 show photos of the floor from either end, including the entry and exit ramps to adjacent floors.

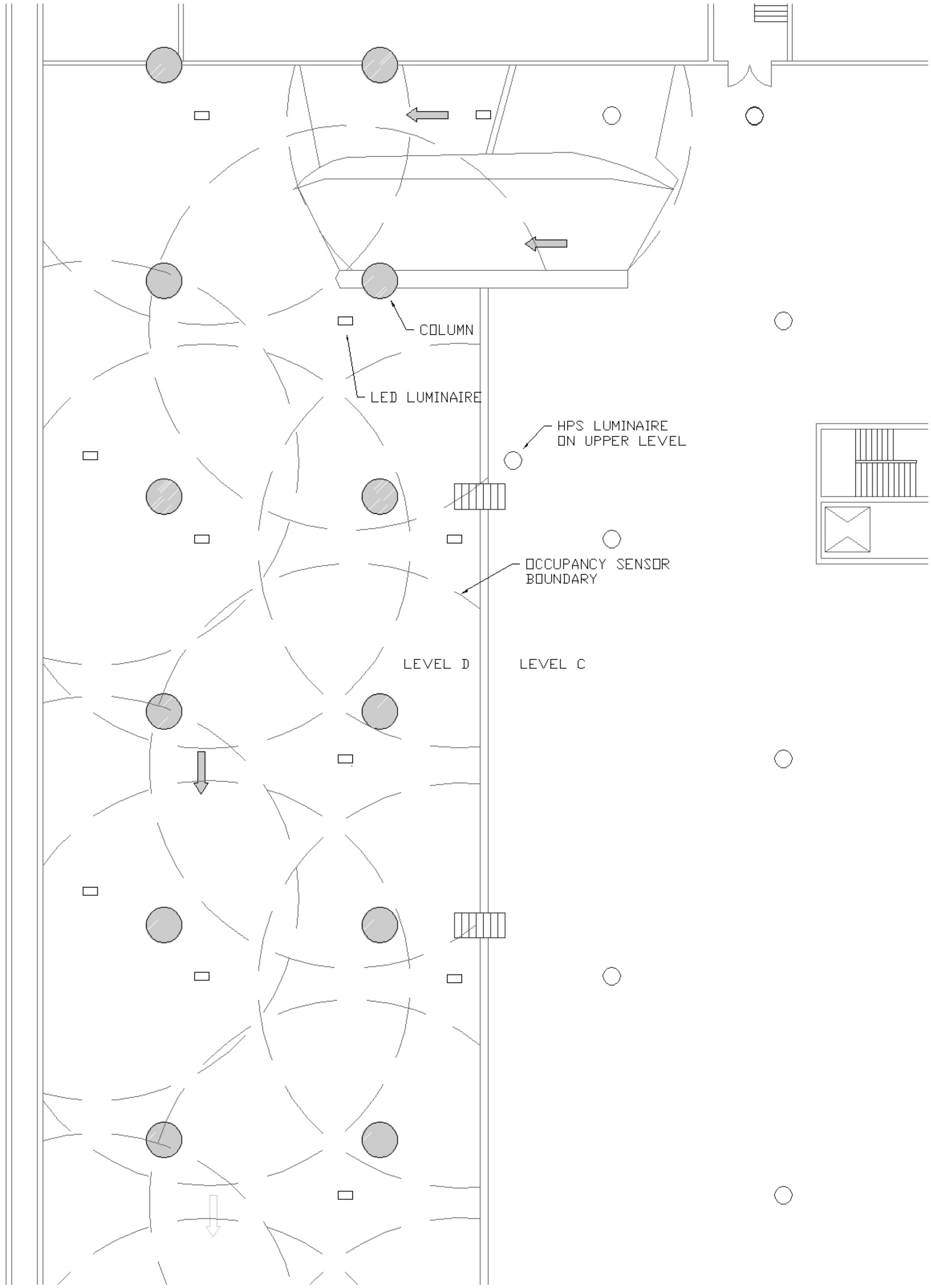


Figure 2.7. Parking Structure Lighting Layout

Figure 2.8. Level D Ramps, Showing Up to Level C (Arrow Up Ramp) and Down to Level E (Foreground)

Figure 2.9. Level D Ramps, Showing Up from Level E (Arrow Shown) and Down from Level C (Foreground)

3.0 Measured Performance

Values presented in this section were either calculated via photometric software or measured in the field or in a photometric testing laboratory, as indicated.

3.1 Lighting Metrics

Calculated and measured illuminance and end-of-life illuminance projections are discussed for both the HPS and LED systems in the following sections.

3.1.1 Design Layout

The designs from garage-to-garage and from floor-to-floor at the DOL Headquarters parking structure are roughly similar in terms of luminaire placement (e.g., luminaires located near columns, luminaires located over ramps, and luminaires located over parking spaces), but exact quantities vary per floor for each garage.

Furthermore, the layout is not uniform across a given floor, with spacing between luminaires varying from 25 to 38 ft due to the locations of columns in the space and the design of the existing electrical system (which was designed around the original fluorescent system). In both systems (HPS and LED), numerous darker areas result from this combination of columns and non-uniform lighting layout.

3.1.2 Calculated Illuminance

Traditional uniformity ratios like average:minimum and maximum:minimum can be subject to an inherent weakness in that they are potentially determined by as little as a single point. Evaluations based solely on those metrics can be misleading, for example, due to a single dark spot falling in a distant corner that has no bearing on the suitability of the overall illumination levels in the space. Such limitations of the metrics are independent of the lighting system employed.

The following tables summarize the calculated illuminance values. In addition to the traditional lighting metrics, the tables also provide a few additional metrics related to the uniformity and distribution of the calculated values across the space.[1] The initial calculations considered the following:

- *Standard deviation* (Std. Dev.) – The standard deviation reflects the distribution across all data points, though its magnitude should still be reviewed in the context of the average value. A standard deviation of 2.3 footcandles (fc) has more context when the average is 3.8 fc than when the average is 20 fc, for example.
- *Coefficient of variation (CV)* – The coefficient of variation is the standard of deviation divided by the mean (average), which provides a useful measure of the relative magnitude of the variation in the data

[1] IES RP-6-01, *Sports and Recreational Lighting*, contains three methods of expressing uniformity: (1) coefficient of variation, (2) uniformity gradient, and (3) uniformity ratios (max:min, max/average, avg/min).

(lower values mean more uniform data). CV is discussed in detail in Illuminating Engineering Society (IES) RP-20-98.[2]

- *Range of points:* Table 3.1 includes the range of points between certain values: 0–1; 1–10; and 10–20 fc. This characterization provides an alternative, straightforward measure of the issue of illumination levels in the space that fall below the desired level: the proportion of measured points that do so. This measure ignores the locations of these points, however, and therefore again provides an incomplete picture if viewed in isolation. Reviewing the values in combination provides more complete information.

Table 3.1. Calculated Initial Horizontal Illuminance Value Summary

	Baseline (HPS)	New System (LED)	RP-20-98
Illuminance[a]			
Average (*average overall)*	7.2 fc	3.8 fc	---
Maximum	18.6 fc	9.2 fc	---
Minimum (absolute minimum)	0.4 fc	0.9 fc	1.0 fc
Uniformity Metrics			
Average:Minimum	18:1	4:1	---
Maximum:Minimum	47:1	10:1	10:1
Standard Deviation	4.5 fc	2.3 fc	---
Coefficient of Variation	0.62	0.40	---
Number of Points	455	455	
Percent of Points Between [b]:			
0 – 1 fc	9%	0%	
1 – 10 fc	63%	100%	
10 – 20 fc	30%	0%	

(a) Light loss factor (LLF) = 1.0 because these are initial calculated values.
(b) Values may not sum to 100% due to rounding.

Both horizontal and vertical illuminances were calculated. Vertical illuminance was calculated at 1.5 meters (5.0 ft) above the parking surface at the point of lowest horizontal illuminance, facing away from the boundaries (per footnote 5 in Table 2 of RP-20-98). Table 3.2 provides the calculated values of vertical illuminance.

Because only 30% of the calculated points for the existing HPS system are below the RP-20-98 recommended value of 0.5 fc, and the minimum value is close enough to this as well; the adequacy of the existing design should not be of concern. The calculations also indicate that the LED design meets the vertical requirement for RP-20-98.

[2] RP-20-98 was recently withdrawn pending update; however, no other applicable recommended practice currently exists so continues to be referenced here.

Table 3.2. Calculated Initial Vertical Illuminance Value Summary

	Baseline (HPS)	New System (LED)	RP-20-98
Illuminance[a]			
Average	1.8 fc	1.6 fc	---
Maximum	6.5 fc	3.6 fc	---
Minimum	0.3 fc	0.5 fc	0.5 fc[b]
Uniformity Metrics			
Percent of Points Between:			
0 – 0.5 fc	30%	0%	
0.5 – 7.0 fc	70%	100%	N/A[c]

(a) Values are initial calculated values and LLF = 1.0.
(b) Maintained, rather than initial illuminance.
(c) RP-20 does not specify uniformity metrics for vertical illuminance.

3.1.3 Measured Initial Illuminance

Illuminance for the HPS installation was measured after 9:00 pm on Friday, April 2, 2010, via a grid with 132 measurement points spaced 10 ft apart (12 rows x 11 columns). Illuminance for the LED products was measured using the same points the next morning following installation.

Table 3.3 summarizes the actual illuminance values measured for the HPS and LED systems. Note that these are initial values with the LED system in the high operating state. Also note that light loss factors (LLFs) have not yet been factored into the scenario; however, doing so may mean that neither system meets RP-20-98 recommendations (see section 3.1.4).

The LED system increases the minimum illuminance by more than 20%, but also reduces the average illuminance values by almost 50% due to the differences in light distribution between the two types of luminaires (discussed in section 2.2). The calculated values (Table 3.1) are similar to the initial measured values but differ slightly because a smaller grid was measured than calculated, the grid was in the center of the floor and did not encompass all parts of the floor, and subtle differences between calculations and measurements are inevitable. By any standard measure of the distribution of lighting points (i.e., average:minimum; maximum:minimum; Std. Dev.; or CV), of the two systems, the LED system provided more uniform lighting.

Table 3.3. Measured Initial Horizontal Illuminance Value Summary

	Baseline (HPS)	New System (LED)	Difference[a]	RP-20-98
Illuminance[b]				
Average	8.44 fc	3.97 fc	-53%	---
Maximum	21.95 fc	7.86 fc	-64%	---
Minimum	0.99 fc	1.20 fc	21%	1.0 fc
Uniformity Metrics				
Average:Minimum	9:1	3:1	---	---
Maximum:Minimum	22:1	7:1	---	10:1
Standard Deviation	5.97 fc	1.39 fc		---
Coefficient of Variation	0.71	0.35	-49%	---
Number of Points	132	144		
Percent of Points Between:[c]				
0 – 1 fc	2%	0%		
1 – 10 fc	55%	100%		
10 – 20 fc	44%	0%		

(a) Negative values indicate a reduction from the baseline to the LED system
(b) Values are initial measured values and LLF = 1.0.
(c) Not all values may sum to 100% due to rounding.

3.1.4 End-of-Life Illuminance Estimates

Light loss factors need to be considered in the lighting system design. The two major LLFs for the systems used in this parking structure application are luminaire dirt depreciation (LDD) and lamp lumen depreciation (LLD).

At the outset of this demonstration, two of the incumbent HPS fixtures were removed, carefully bagged to preserve their “as found condition,” and sent for testing. The HPS fixtures were tested as delivered and then cleaned and tested again. The average LDD between the two states of both fixtures was calculated to be 2.5%.[3] Their last date of cleaning while in the garage is unknown.

Lamp lumen depreciation is the reduction in output that lighting sources typically experience over time. For appropriate sizing of luminaires during the design process, the typical LLD value used for HPS is 0.85 (but can range between 0.80 and 0.90). Estimating LLD for LED systems is a more complex procedure that is still under development, and no current set of data consistently expresses either the depreciation value or the approximate point in time at which it occurs. In lieu of a standard calculation procedure, L_{70} (70% of initial illuminance) is a current common default value used for LED lamp lumen depreciation.[4] The manufacturer also provides an L_{70} value in their specification sheet (see Appendix A). Table 3.4 projects future horizontal illuminance using the following LLFs:

LDD = 97.5% for both HPS and LED system

LLD = 85% for the HPS system and 70% for the LED system

[3] Luminaire 1: 6,745 lm (“as is”) / 6,868 lm (“clean”) = 97%; Luminaire 2: 7,590 lm (“as is”) / 7,791 lm (“clean”) = 98%. Note this value is consistent with the luminaire dirt depreciation factor in Figure C.1 in RP-20-98 for 3–4 years of exposure in a “very clean” atmosphere.
[4] L_{70} and /or lamp lumen depreciation is often used as a proxy for LED luminaire lifetimes, but the actual lifetime of an LED system is a function of multiple components and their collective reliabilities.

Table 3.4. Projected Horizontal Illuminance Value Summary[a]

	Baseline (HPS)	New System (LED)	Difference	RP-20-98
Average	6.99 fc	2.71 fc	-69%	---
Maximum	18.19 fc	5.36 fc	-71%	---
Minimum	0.82 fc[b]	0.82 fc[b]	0	1.0 fc

(a) Values derived from measured illuminance (Table 3.3).
(b) Red values highlight a *potential* concern; in this case the minimum value does not strictly meet the RP-20 recommended level.

Table 3.4 shows projected illuminance for each source taking the relevant LLFs into account, but neglects the different points in time at which these values occur. HPS lamps typically have a life between 24,000 and 30,000 hours, and manufacturers report their mean (or design) lumens at 40% of rated life. Following this methodology means that the HPS luminaires at this site will reach the listed values between 1 and 1.5 years after installation.[5]

The corresponding period to reach the listed values for LEDs is more difficult to predict. LED life calculations are still being revised and validated by the lighting community, and variable factors of operation such as the frequency of garage use and time delay setting can be expected to affect LED system life as well.

Philips Wide-Lite's data sheet (see Appendix A) at the time noted a rated LED life of 60,000 hours per chip testing at a maximum junction temperature (T_j) of 127 °C, but claimed a much longer potential LED life expectancy (B_{10}, L_{70}) at the lower operating temperatures expected in most installations (e.g., 156,600 hours at 25 °C).[6] Using these two example values to bound the estimates means the LED system would reach the illumination levels in Table 3.4 somewhere between about 7 and 18 years after installation.[7]

3.2 Energy Calculations

Energy usage was determined by measuring power on site and devices installed at the luminaire to track operation of the luminaire.

3.2.1 Electrical Measurements

Electrical measurements were taken prior to illuminance measurements to verify energy usage and savings of the systems. The measured values in Table 3.5 show the LED system drawing approximately half the power of the HPS system in its full or high power state.

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[5] 40% of 24,000 hours = 9,600 / 8,760 hours/year = 1.1 years; 40% of 30,000 hours = 1.4 years.

[6] In this case, 25 °C represents the ambient air temperature rather than the chip junction temperature, but the corresponding junction temperature in such an environment is expected to be something well below 127 °C. See the product datasheet in Appendix A.

[7] 60,000 / 8,760 hours = 6.8 years; 156,000 / 8,760 hours = 17.8 years.

Table 3.5. Summary of Measured Electrical Parameters

	Baseline (HPS)			
	Range[a]	Average[b]	New System (LED)[b,c]	Difference
Volts (V)	277		280	---
Current (A)	0.49 – 0.60		0.23	-55%
Power Factor	0.95 – 0.79		0.96	---
Watts	129.3 – 129.7	129.5	61.8	-52%

(a) Among multiple luminaires tested. Such variations are commonly found in field measurements, particularly after years of operation.
(b) Value used for calculations.
(c) In high state of operation.

3.2.2 Energy Use

The reduced power draw of the LED product translates directly into corresponding energy savings if the operating hours remain the same. Energy savings are further enhanced by the addition of occupancy sensors, however, which are designed to subsequently reduce the hours of high-state operation. As noted, the motion sensors in this installation reduce the luminaire power draw to 10% (or 6.2 W) in the low state of illumination. Relative to the 129.5 W of the incumbent HPS, at this setting the sensors increase the 52% initial power reduction to 95% while operating in the low state.

In the end, actual energy savings are determined by the time split realized between high and low power operating states, and can vary from day to day or from luminaire to luminaire, depending on patterns of garage use. Accurate estimation of this time split over longer durations is best accomplished by monitoring a number of individual luminaires and recording the times spent in each of the respective operating states. Consistency of building use in turn determines whether the recorded data can be adequately used for projecting savings into the future.

3.2.3 Measurement Protocol

The metering approach used in this study included the installation of a current transformer (CT) on a hot leg of the electrical supply of each individually metered luminaire. The output of the CT was received by a data logger that time stamped and recorded the corresponding amperage readings. Due to limited precision of the CTs, their readings were used only to indicate the relative high or low state of the luminaire. The corresponding amperage values were manually documented with a separate electrical meter. Figure 3.1 presents the CT and data logger configuration as installed on an LED luminaire.

For each day of monitoring, 1,440 data points (24 hours with 60 readings per hour) were gathered. Approximately 1.5 million measurements (10 luminaires x 106 days x 1,440 measurements per day) were gathered in total.

Figure 3.1. Current Transformer and Data Logger Installation on LED Luminaire at the Frances Perkins Building

3.2.3.1 Baseline Measurements

One of the baseline HPS luminaires was monitored continuously for 64 days to confirm it was energized 24 hours per day including weekends, or 8,760 hours per year. Figure 3.2 shows a representative set of data for one day, which remained consistent throughout the period.

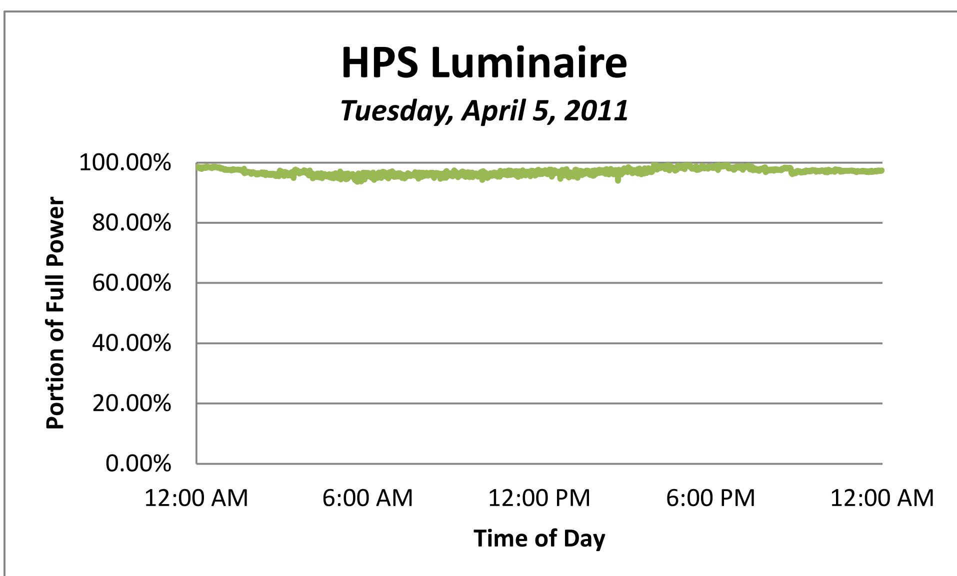

Figure 3.2. Weekday Measurements of HPS Luminaire

3.2.3.2 Bi-level Luminaire Measurements – Long Time Delay

Ten LED luminaires were monitored over a total of 85 days during three periods between April 1 and September 25, 2011, with an initial time delay setting of 10 minutes.[8] Figure 3.3 shows the breakdown of high state operation by day of the week. (During the remaining periods in the chart, the luminaires were in low state because they are never turned off.) On weekdays, the luminaires operate in the high state roughly 60 percent on average over a 24-hour period, or about 14.4 hours. The percentage of time spent in high state during weekends drops substantially, as expected, comprising on average only 15% of operation, or about 3.6 hours per day.

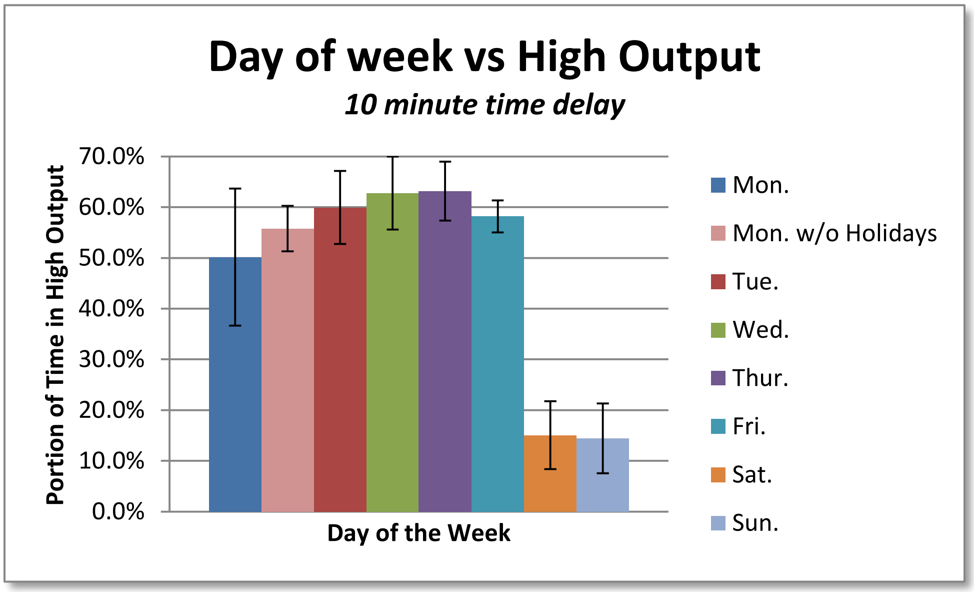

Figure 3.3. Luminaire High Output as a Function of Day of the Week at 10-Minute Delay Setting

During this initial monitoring phase, the office was closed for two federal holidays, Memorial Day and Labor Day, which had a marked effect on the daily average. In Figure 3.3, the data for Mondays with the two holidays excluded is shown alongside the other data, bringing it more in line with the other days of the week. Table 3.6 provides a summary average of weekday and weekend values, and the combined overall total.

Table 3.6. Average Portion of Each Day Luminaire Operated in High State for Long Time Delay

	Summary of Average Time in High Output		
	Weekday	Weekend	Combined Total
Average	58.8%	14.8%	46.8%
Removing Holidays	60.0%	14.8%	47.4%

[8] Actual periods of monitoring were April 3 - June 12; July 17 - August 14; and September 4 – 25. See Appendix B for more detail on the metered results.

3.2.3.3 Bi-level Luminaire Measurements – Short-Time Delay

The delay setting, or time between last detected motion and switching to low state, need only be long enough to cover the typical time required for a vehicle to enter the area and park, with perhaps a short additional period while occupants gather their things before exiting the vehicle. The motion sensors will again be activated the moment a door is opened (assuming adequate sensor coverage) or at least when the occupant crosses into a zone covered by the system, which then continues to provide illuminated passage to the building entrance. Following the first several months of operation, it was surmised that the default 10-minute delay setting was much longer than necessary. The time delay was reduced to 2.5 minutes and the luminaires were subsequently monitored for 42 days between December 11, 2011 and March 9, 2012.

Reducing the time delay significantly affected the luminaire operation and its consequent energy use. As Figure 3.4 shows, the average operating periods at the 2.5-minute delay setting were only about 25% or less in high state, versus the roughly 60% at the previous 10-minute delay setting.

Again during this monitoring period holidays occurred, including Christmas, New Year's Day, and President's Day. Once the holidays were removed from the Monday mean, Mondays again showed a profile similar to the other days of the week.

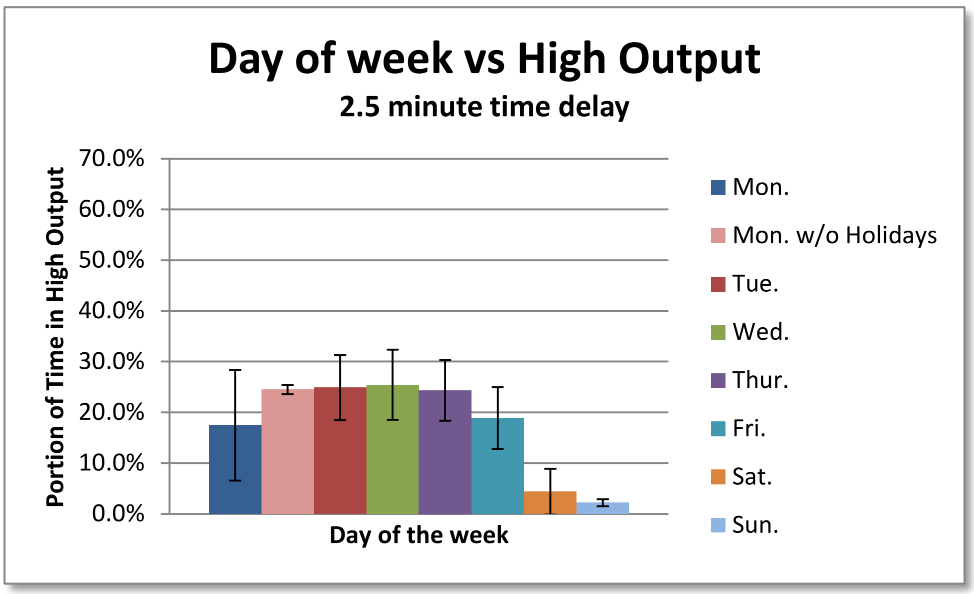

Figure 3.4. Luminaire High Output as a Function of Day of the Week at 2.5-Minute Delay Setting

Table 3.7 provides a summary average of weekday and weekend values, and the combined overall total.

Table 3.7. Average Portion of Each Day Luminaire Operated in High State for Short Time Delay

	Summary of Average Time		
	Weekday	Weekend	Combined Total
Average	19.2%	3.3%	16.8%
Removing Holidays	20.4%	3.3%	17.8%

Hence, simply reducing the delay setting from 10 to 2.5 minutes decreased the average period of high state operation among the metered luminaires by approximately two-thirds.

3.2.4 Energy Use Summary

Table 3.8 presents the resulting energy use and energy savings estimates of the different lighting systems under the varying operating conditions. Energy savings relative to the original HPS baseline amounted to 76% at the 10-minute setting and 88% at the 2.5-minute setting. Comparing only between the two LED results, the 2.5-minute delay adjustment reduces energy use by 50% compared to the 10-minute setting.

No complaints about the shorter delay setting have been received from the parking structure users to date, possibly because few may have even noticed the change.

Table 3.8. Summary Results of Annual Energy Use and Savings

Luminaire and Delay Setting	Annual Energy Use (kWh/yr per luminaire)	Annual Energy Savings (kWh/yr per luminaire)	Savings
Baseline HPS	1,134.42	NA	NA
Phase 1: LED (10-minute delay)	270.70	863.70	76%
Phase 2: LED (2.5-minute delay)	136.42	998.00	88%

The effect of reducing the time delay is evident in Figure 3.5 and Figure 3.6, which show the operating pattern for the same luminaire on the same day of the week, though on different dates corresponding to the separate delay settings. Although the patterns appear quite similar in aggregate, the more frequent switching between high and low states resulting from the shorter delay setting makes the latter much more active.

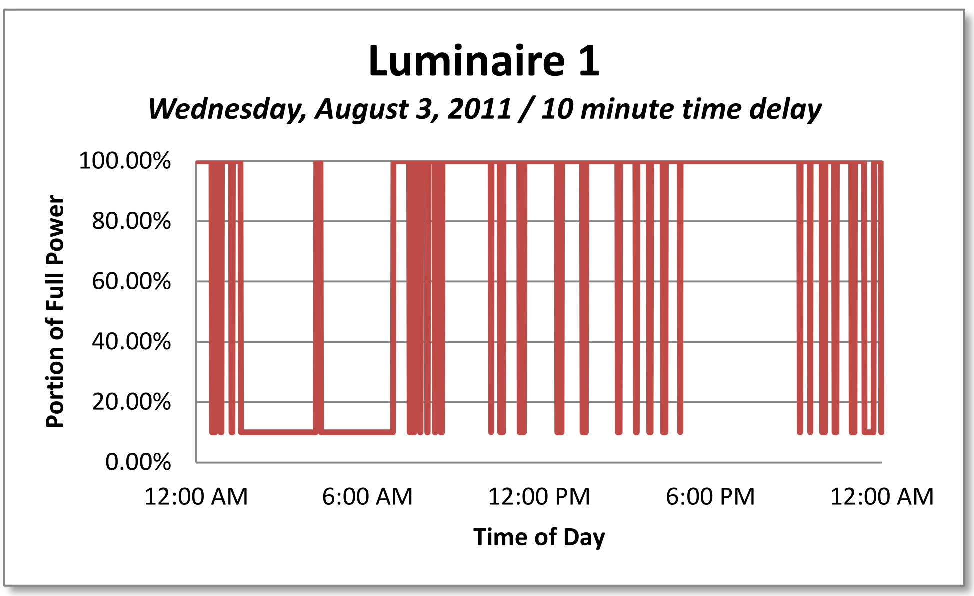

Figure 3.5. LED Luminaire Operating Profile (10-Minute Delay), Wednesday, August 3, 2011

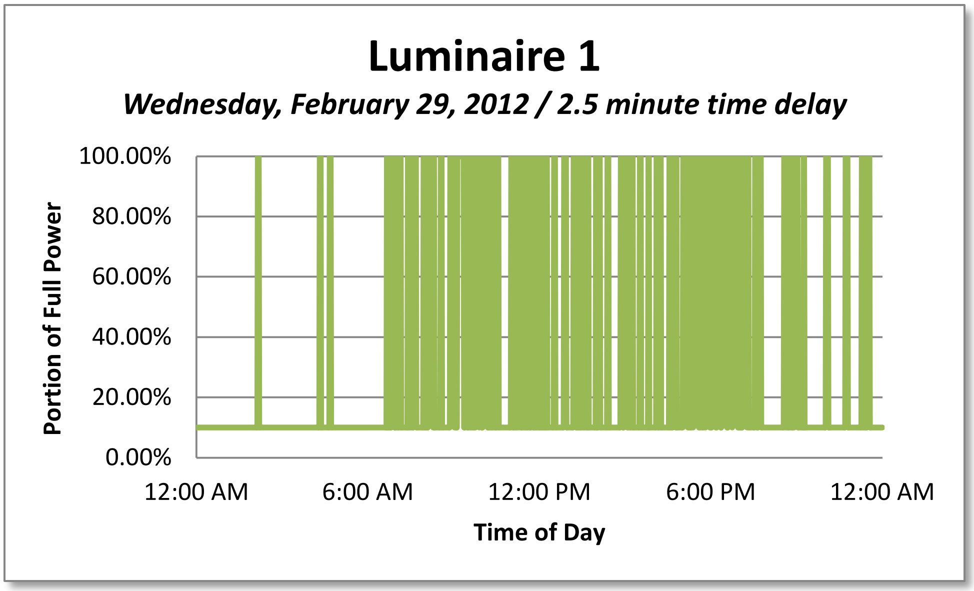

Figure 3.6. LED Luminaire Operating Profile (2.5-Minute Delay), Wednesday, February 29, 2012

3.2.5 False Tripping

During the evaluation at the 10-minute delay setting, a number of luminaires exhibited markedly anomalous behavior during one or more 24-hour periods. Figure 3.7 shows a week's operation of one example of such behavior by a luminaire, which switched into its high state of operation starting about 7:30 am on May 23, 2011, and continued almost unabated until later the following week. In all, 6 of the 10 metered luminaires in the garage set to the 10-minute delay returned data similarly indicating at least one 24-hour period of extensive use (greater than 80% of the day spent in high state operation) over the full monitoring period. One luminaire near the driving ramp from the next floor showed 23 days of such behavior, out of 85 days monitored. Although not an impossibility, this many days of legitimate activity on the part of one or two luminaires without seeing similar behavior in other luminaires is unlikely.

After the time delay was reduced to 2.5 minutes, however, the abnormal behavior observed dropped dramatically. Again, one of the luminaires near the ramp from the next floor returned one 24-hour period at 94% high state operation, while data from another luminaire located along a back wall indicated a 100% high state day over a weekend period. Overall, however, such apparent faulty behavior almost disappeared, at least in terms of the ability to distinguish it from normal background behavior in the metered data.

Speculations were made regarding the potential causes of the anomalous behavior, but it ultimately could not be resolved during this evaluation. One of the more plausible explanations suggested by the manufacturer involves sufficiently high air flows directed across the sensors of the subject luminaires. A few of the luminaires are located in areas of high ventilation air flow and therefore could be subject to relatively high air speeds, although exactly how this causes false tripping behavior is not well understood. Furthermore, it seems unlikely that this single factor could explain all false tripping behavior observed during this project. Ultimately, the contribution of false tripping in the reported cumulative energy use is estimated at less than 5%.

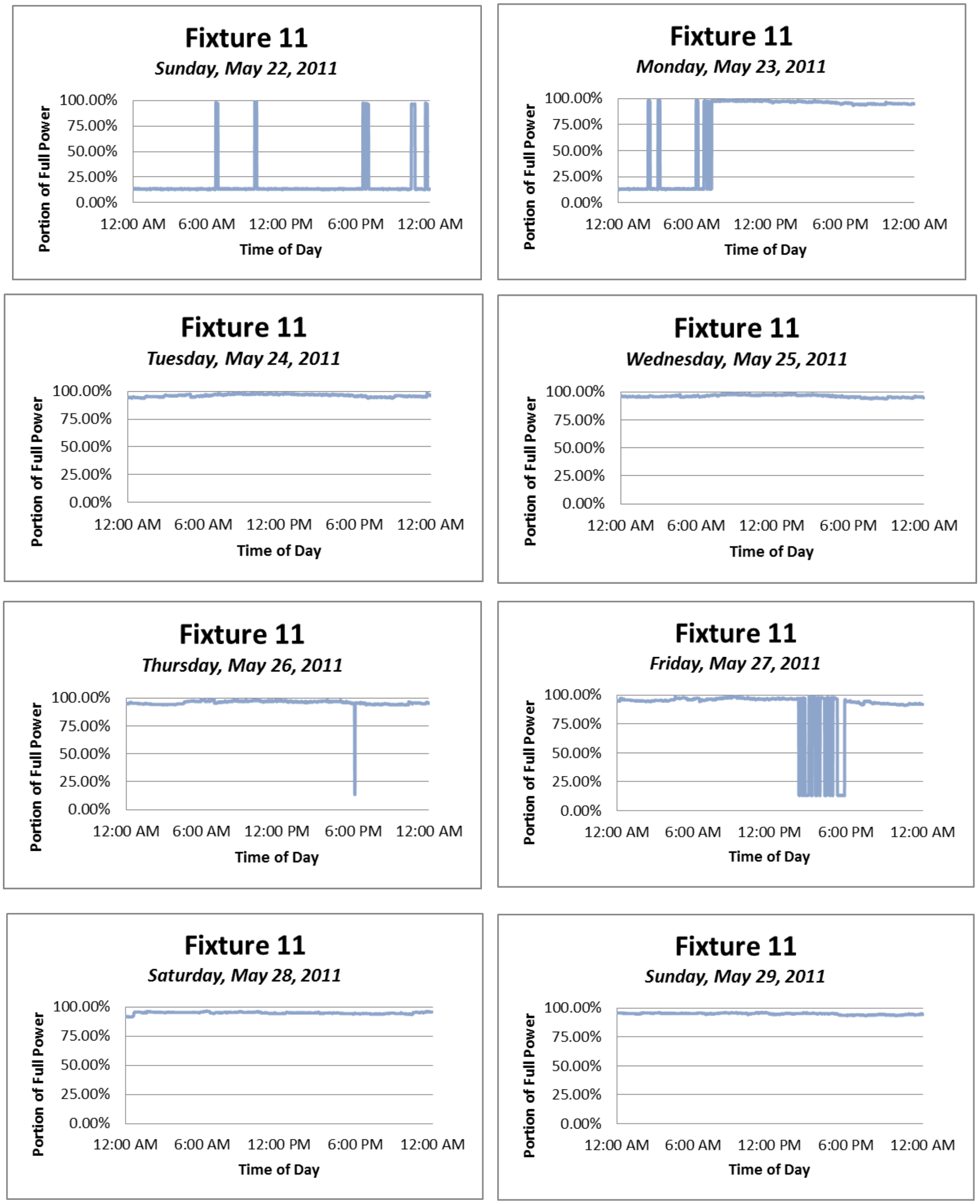

Figure 3.7. Anomalous Behavior of One Luminaire That Exceeded More than One Week

4.0 Cost Effectiveness

Cost effectiveness is typically one of the first criteria for evaluating energy efficiency upgrades. Different methods exist for evaluating cost effectiveness, ranging from simple to complex. This evaluation includes a simple payback calculation because of its general familiarity throughout the business community. However, because of significant weaknesses associated with the methodology for results extending beyond a few years, life-cycle cost (LCC) and savings-to-investment ratio (SIR) assessments are also included.

4.1 Inputs to the Analysis

The values used in this report apply to the DOL Headquarters site, for the time this evaluation was conducted. Other sites may vary in terms of operating schedules, energy tariffs, applicable maintenance rates, and other factors. Even the assumptions for this location will become outdated over time as LED luminaires continue to decrease in price while increasing in efficacy from year to year. Readers of this report should consider their own applicable and up-to-date parameters when performing similar calculations.

4.1.1 Operating Schedules

The baseline operating schedule is 8,760 hours (24 hours per day, 365 days per year). Each of the following four operating scenarios is examined in this analysis:

1. High output only – assumes no sensor control and that the LED luminaire operates in high output the entire period. This scenario is further subdivided into 1a - not including the cost of the sensor, and 1b - including this cost.

2. Bi-level with long (10-minute) time delay – assumes that the sensor is in operation and operates the lighting in the high state, on average, 47% of the time[1] (or conversely, reduces the output to 10% of full power 53% of the time).

3. Bi-level with short (2.5-minute) time delay – assumes that the sensor is in operation and operates the lighting in the high state, on average, 17% of the time (or conversely, reduces the output to 10% of full power 83% of the time).

4. Low output only – assumes no sensor control and that the LED luminaire operates in low output the entire time.

Scenarios 1 and 4 are unlikely in typical operation, but serve to bound the maximum/minimum results of the analysis. Scenarios 2 and 3 represent the actual situations realized with the two time delay settings investigated in this installation.

[1] The percentages used in scenarios 2 and 3 are derived from the metered data reported in Table 3.6 and Table 3.7.

4.1.2 Maintenance Costs and Costs of Equipment

Based on a review of related documentation, the price of a 100 W HPS lamp using GSA Advantage[2] is approximately $50. Assuming the lamp will be replaced every 2.7 years (24,000 hours life / 8,760 hours per year) yields an annual lamp cost of $18.25.

Per the Bureau of Labor Statistics (BLS), the 2010 median pay for electricians was $23.20 per hour ($48,250 per year), and the 2010 median pay for a construction laborer/helper was $13.66 per hour ($28,410 per year) (BLS 2012). Replacing a lamp may not always require the skills of an electrician; therefore, an average ($18.43) of the electrician and helper hourly rates is used to estimate the cost of lamp maintenance.

This study assumes that lamp replacement requires approximately 15 minutes, translating to an estimated cost of $4.60. However, retrofitting an HPS luminaire with an LED luminaire is assumed to require 1 hour of an electrician's time (or $23.20/luminaire).

At the time of this installation, the LED luminaires cost $1,031 each, including the optional occupancy sensor cost of $195. For analysis in a new construction scenario, a new HPS luminaire price of $173 was assumed.[3]

4.1.3 Energy Tariffs, Analysis Period, and Discount Rate

For cost effectiveness calculations, a melded rate of $0.168/kWh was used for the energy tariff.[4] To calculate the LCCs, an energy tariff escalation factor developed by the U.S. Energy Information Administration was applied to this rate.

Because of its size and location in Washington, DC, the Frances Perkins Building will likely be a long-term asset for DOL. An analysis period of 20 years was selected for the LCC analysis.

Discount rates will vary by site based on the cost of capital for a given user. A 3.0% discount rate was assumed for this government site.

4.2 Simple Payback Calculation

Simple payback considers only the initial cost of the equipment and a limited number of other variables, and typically does not factor in discount rates or future escalations in labor and energy costs, etc. A simple payback calculation is most often (and best) used as a first hurdle test, with more detailed cost/benefit analysis following if the first hurdle is successfully passed.

This analysis compared the installed cost of the luminaire and occupancy sensor against the estimated reduction in operating costs between the existing and new systems.

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[2] GSA Advantage (https://www.gsaadvantage.gov/advantage/main/start_page.do) is an online shopping and ordering system that provides access to thousands of contractors and millions of supplies (products) and services.

[3] GSA Advantage search for a parking structure resulted in a similar type of fixture, lamp type, and wattage. The Exceline PGQ10LXL-8 was used for pricing (lamp included).

[4] Electricity rate varies per service territory based on size and usage characteristics. This rate is from PEPCO and applies to this site. See Appendix C for a breakdown of the applicable costs.

4.2.1 Retrofit Setting

Table 4.1 provides results for the four operating scenarios examined, where the simple payback ranged from 10.9 years (scenario 1b) to 5.9 years (scenario 4). The occupancy sensor introduces a significant added cost that must be recovered. However, as operating benefits of the sensor are increasingly utilized in scenarios 2 and 3, the time to reach simple payback quickly decreases. The relatively small difference between scenarios 3 and 4 illustrates that scenario 3 has come close to achieving the shortest payback possible under the given conditions.

Table 4.1. Retrofit Simple Payback

Scenario	Description	Source Type	Initial Luminaire Price (2010)	Annual Operating Costs	Simple Payback (years)
1a	High output only (no sensor)	HPS	---	$182.35	
		LED	$836	$87.31	8.8
1b	High output only (includes sensor)	HPS	---	$182.35	
		LED	$1,031	$87.31	10.9
2	Long time delay (10 min)	HPS	---	$182.35	
		LED	$1,031	$46.47	7.6
3	Short time delay (2.5 min)	HPS	---	$182.35	
		LED	$1,031	$20.58	6.4
4	Low output only	HPS	---	$182.35	
		LED	$1,031	$8.68	5.9

4.2.2 New Construction Setting

The same four scenarios were assumed for an analysis pertaining to new construction. In this situation, the labor to install either the HPS or the LED luminaire is assumed to be the same and thus drops out of the calculation when comparing the two alternatives. Power supply (either the HPS ballast or LED driver) failure will occur at some point, and is assumed to be roughly equivalent in both frequency and cost between the technologies, so it also drops out in the comparison between them.

Table 4.2 provides results of the four operating scenarios examined, where the simple payback ranged from 4.9 to 9.0 years. As in the retrofit scenario, increasing use of the sensor improves the simple payback relatively rapidly. The short time delay setting likewise enables the system (luminaire + sensor) to nearly achieve the maximum possible savings.

Table 4.2. New Construction Simple Payback

Scenario	Description	Source Type	Initial Luminaire Price (2010)	Annual Operating Costs	Simple Payback (years)
1a	High output only (no sensor)	HPS	$173	$182.35	
		LED	$836	$87.31	7.0
1b	High output only (includes sensor)	HPS	$173	$182.35	
		LED	$1,031	$87.31	9.0
2	Long time delay (10 min)	HPS	$173	$182.35	
		LED	$1,031	$46.47	6.3
3	Short time delay (2.5 min)	HPS	$173	$182.35	
		LED	$1,031	$20.58	5.3
4	Low output only	HPS	$1173	$182.35	
		LED	$1,031	$8.68	4.9

4.3 Life-Cycle Costs

LCC analyses were performed both for retrofit of the existing system with the LED product and for a new construction scenario. The initial cost of the LED luminaire has a large influence on the LCC results, as do the expected energy savings. In contrast, maintenance has less effect in this particular location because the luminaires are mounted rather low (less than 10 feet) and can be serviced by a single person with very little equipment (e.g., ladder or lift).

An advantage of LCC relative to simple payback analysis is that LCC takes into account the expected lifetime of the product. Simple payback by itself gives no indication of whether the calculated result falls within the operating lifetime of the product. In the following scenarios, product lifetime assumptions of 60,000 hours and 156,600 hours (discussed previously) are used to bound the analysis. Values in red in the tabulated results indicate that costs exceed savings over the lifetime of the product in that scenario (i.e., that payback does not occur before the product is expected to require replacement).

4.3.1 Retrofit Setting

Table 4.3 compares the LCCs in a retrofit setting. In general, as the scenarios progress from no use of sensors to sensors operating with the short time delay, the net savings increase for LED. The one exception is in the upper boundary represented by scenario 1b, where the sensor has been purchased but is not being used (i.e., despite having a sensor, the luminaire remains in high state operation all of the time). The table effectively illustrates the importance of taking advantage of the sensor's capabilities to the maximum extent acceptable in the application.

Table 4.3. Life-Cycle Cost Analysis for the Retrofit Scenario

Scenario	Description	Source Type	Life-Cycle Costs (60,000 Hour Life)	Net Savings (Net Present Value) (60,000 Hour Life)	Life-Cycle Costs (156,600 Hour Life)	Net Savings (Net Present Value) (156,600 Hour Life)
1a	High output only (no sensor)	HPS	$2,877.87		$2,877.87	
		LED	$3,239.82	*-$361.96*	$2,113.02	$764.82
1b	High output only (includes sensor)	HPS	$2,877.87		$2,877.87	
		LED	$3,714.69	*-$836.82*	$2,325.06	$552.81
2	Long time delay (10 min)	HPS	$2,877.87		$2,877.87	
		LED	$3,151.50	*-$273.64*	$1,761.87	$1,115.99
3	Short time delay (2.5 min)	HPS	$2,877.87		$2,877.87	
		LED	$2,794.52	$83.35	$1,404.89	$1,472.98
4	Low output only	HPS	$2,877.87		$2,877.87	
		LED	$2,630.44	$247.42	$1,240.81	$1,637.05

4.3.2 New Construction Setting

Table 4.4 compares the LCCs in a new construction setting. The new cost of an HPS luminaire must be factored into this scenario, increasing that technology's corresponding LCC compared to a retrofit situation. Consequently, the net savings from LED is also greater in new construction than in retrofit.

Table 4.4. Life-Cycle Cost Analysis for the New Construction Scenario

Scenario	Description	Source Type	Life-Cycle Costs (60,000 Hour Life)	Net Savings (Net Present Value) (60,000 Hour Life)	Life-Cycle Costs (156,600 Hour Life)	Net Savings (Net Present Value) (156,600 Hour Life)
1a	High output only (no sensor)	HPS	$3,004.54		$3,004.54	
		LED	$3,239.82	*-$235.28*	$2,113.02	$891.52
1b	High output only (includes sensor)	HPS	$3,004.54		$3,004.54	
		LED	$3,714.69	*-$710.15*	$2,325.06	$679.48
2	Long time delay (10 min)	HPS	$3,004.54		$3,004.54	
		LED	$3,151.50	*-$146.96*	$1,761.87	$1,242.67
3	Short time delay (2.5 min)	HPS	$3,004.54		$3,004.54	
		LED	$2,794.52	$210.02	$1,404.89	$1,599.65
4	Low output only	HPS	$3,004.54		$3,004.54	
		LED	$2,630.44	$374.10	$1,240.81	$1,763.73

4.4 Savings-to-Investment Ratio

The savings-to-investment ratio is the ratio of the present value savings to the present value costs of an energy conservation measure. An SIR greater than 1.0 indicates a sound investment, whereas values below 1.0 show that costs exceed savings over the lifetime of the product. This indicator is dimensionless.

4.4.1 Retrofit Setting

Table 4.5 lists the SIR for the four different scenarios under a retrofit setting. Similar to the LCCs above, the different lifetime assumptions have a varied impact on the SIR. In all cases that include the sensor, the SIR improves as the energy savings increase, as would be expected given that additional savings do not entail any additional costs.

Table 4.5. Savings-to-Investment Ratio for Retrofit

Scenario	Description	Source Type	60,000 Hour Life	156,600 Hour Life
1a	High output only (no sensor)	HPS LED	0.78	2.40
1b	High output only (includes sensor)	HPS LED	0.61	1.73
2	Long time delay (10 min)	HPS LED	0.87	2.47
3	Short time delay (2.5 min)	HPS LED	1.04	2.94
4	Low output only	HPS LED	1.12	3.16

4.4.2 New Construction Setting

Table 4.6 lists the SIR for the four different scenarios under a new construction setting. Again, the assumed lifetime has a pronounced effect on the SIR, as does the increasing energy savings achieved through each successive scenario.

Table 4.6. Savings-to-Investment Ratio for New Construction

Scenario	Description	Source Type	60,000 Hour Life	156,600 Hour Life
1a	High output only (no sensor)	HPS LED	0.85	3.13
1b	High output only (Includes sensor)	HPS LED	0.65	2.08
2	Long time delay (10 min)	HPS LED	0.93	2.97
3	Short time delay (2.5 min)	HPS LED	1.10	3.54
4	Low output only	HPS LED	1.19	3.80

5.0 Discussion

5.1 Illuminance

Although the LED system produces a lower average illuminance than the HPS system, it offers a higher initial minimum value. Once the applicable light loss factors are taken into account, however, over time both lighting systems are projected to coincidentally reach the same minimum illuminance value of 0.82 fc. Note that this shared value is slightly lower than the minimum recommended by IES for parking structures, 1.0 fc, in RP-20-98.

Missing the targeted level by this minor amount is unlikely to be of concern, and is primarily due to the combination of the non-uniform lighting layout and the location of the columns, which result in shadowing. RP-20-98 acknowledges the disproportional effect of shadowing on uniformity metrics, and proposes as an alternative deriving the minimum from a small area between luminaires rather than from a single point. Strict adherence to the recommended minimum throughout the garage would likely otherwise require the installation of supplemental luminaires for both the HPS and the LED systems.

5.2 Energy Savings

Significant energy savings have been achieved in this installation, in particular owing to the 24/7 lighting operation in the facility. The willingness of the building staff to experiment with the occupancy sensor settings further contributed to an ultimate gain that was even greater than expected.

Figure 5.1 illustrates the relative impact of the various scenarios investigated in this evaluation, starting with the original HPS lighting. The columns show the estimated annual energy use per luminaire and the incremental percentage drop progressing through each successive scenario: 1) substituting the LED product for HPS (52 % savings); 2) control of luminaire operation using the occupancy sensors set at 10-minute delay (50.2 % incremental savings); and 3) the shortened delay of 2.5 minutes (49.6 % incremental savings).

As the potential savings in any installation are finite, such incremental actions produce asymptotic results (i.e., diminishing returns become increasingly evident in the figure as the baseline energy use becomes progressively smaller). Individual contributors to the savings achieved are discussed in the following subsections.

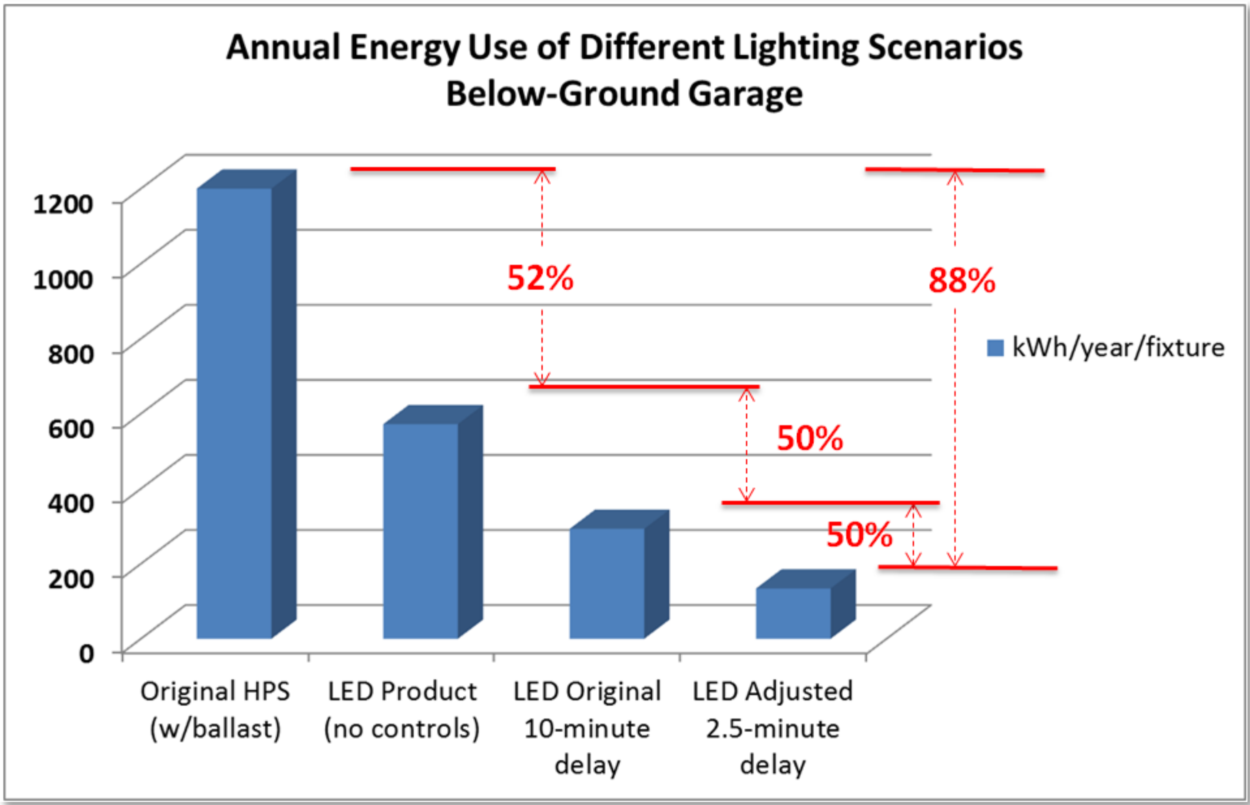


Figure 5.1. Estimated Annual Energy Use and Relative Savings from Different Lighting Scenarios

5.2.1 User-Adjustable Settings

Figure 5.2 depicts how energy savings of the new occupancy sensor-based LED system varies with different time delay and low-state power settings. Most of the savings from this installation come from the initial conversion from HPS to LED. This level is represented as the point of minimum savings in the figure and is the level of savings that would have been achieved without an occupancy sensor control system.

The lines in Figure 5.2 plot the energy savings potential as a function of the percentage reduction in power output (i.e., from high state to low), using the operating time splits (actual time spent in each state) measured in this field study. It is readily apparent that both decreasing the time delay and increasing the percent reduction in power draw between states significantly contribute to the savings achieved. In this installation, the low state setting at 90% reduction from full power helps deliver savings near its maximum potential under either time delay scenario.

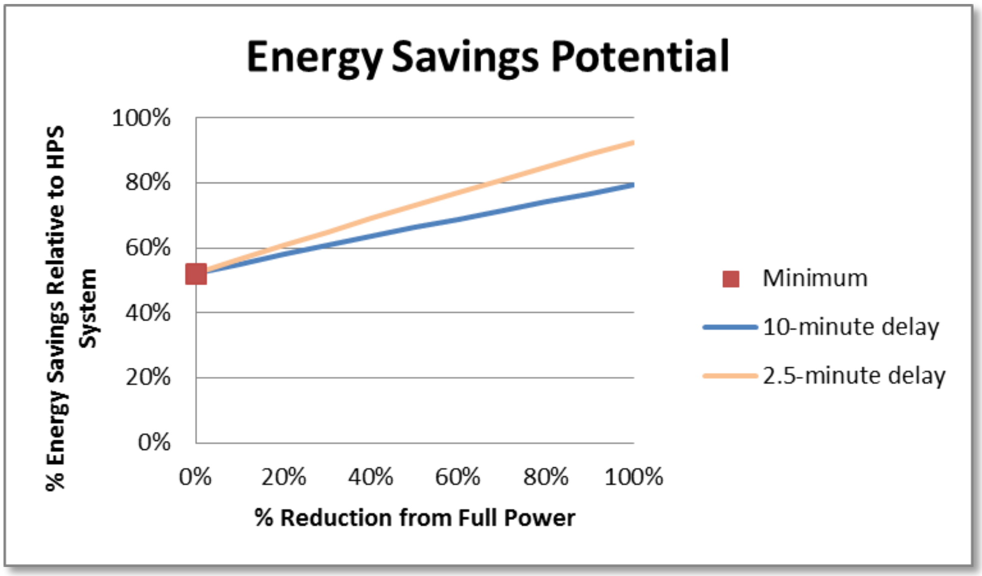


Figure 5.2. Energy Savings Potential from Occupancy Sensors

5.2.2 Building Use Schedules

Much of the expected savings from a given system depend on the schedule of the building or the site that the parking structure supports. If this parking structure were located next to a busy retail center instead of an office building, for example, its energy use profile would differ not only across the times of day but also in the total time spent in high state operation.

Over the analysis period, energy use was markedly lower on Mondays compared with other weekdays. In part this is because federal holidays are frequently observed on Mondays, although even when holidays were excluded Mondays and Fridays still had lower average energy usage than the middle of the week. This is to be expected and is probably driven by vacation schedules and long weekends and more staff teleworking on those days, among other well-established reasons.

This finding underscores the importance of factoring the schedule of the site and supported buildings into energy savings estimates. If a parking structure supports a building where staff observe seasonal hours (e.g., universities and retail environments), much higher savings may be achieved during those periods of lower use.

5.2.3 Time of day use

The long (10-minute) delay setting created a situation where apparent usage (i.e., luminaire operation in high state) was roughly equal during “work hours” (defined in this case as 8:00 am to 6:00 pm) and “after hours” (6:01 pm to 7:59 am), as illustrated in Figure 5.3.

Also of note, the observed standard deviation was smaller during work hours than during after-hours. Such similar measured results for the two periods of the day at first seems counterintuitive, but in fact it requires only a single event every 9 minutes on average to maintain the lighting system in a perpetual high state.

In contrast, after the time delay setting is reduced, system usage during the work day relative to after hour periods is much more consistent with expectations (Figure 5.4). In this setting, the lighting spends roughly 1.5 times more time in high state during the workday than during after-hour periods despite the after-hour period being considerably longer (14 hours vs. 10 hours). This relationship is skewed by the weekend operation. During weekends, the after-hours periods actually saw more usage than during the daytime. This could be because the winter monitoring period had fewer weekend workers or just that security and cleaning crews are busier in the winter.

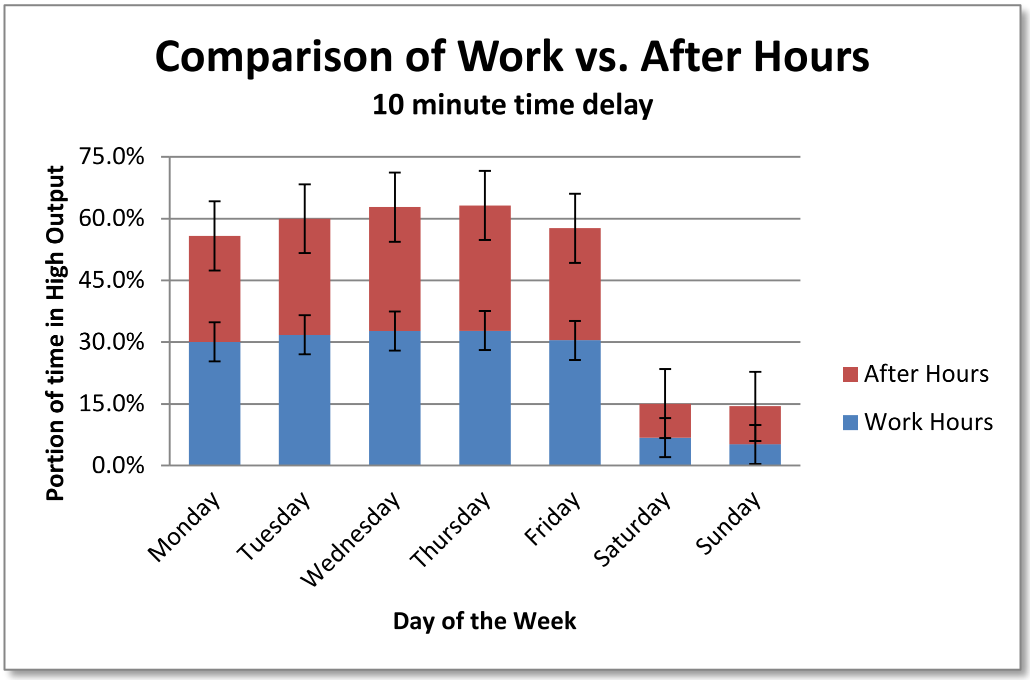


Figure 5.3. Comparison of Operation by Time of Day (10-Minute Time Setting)

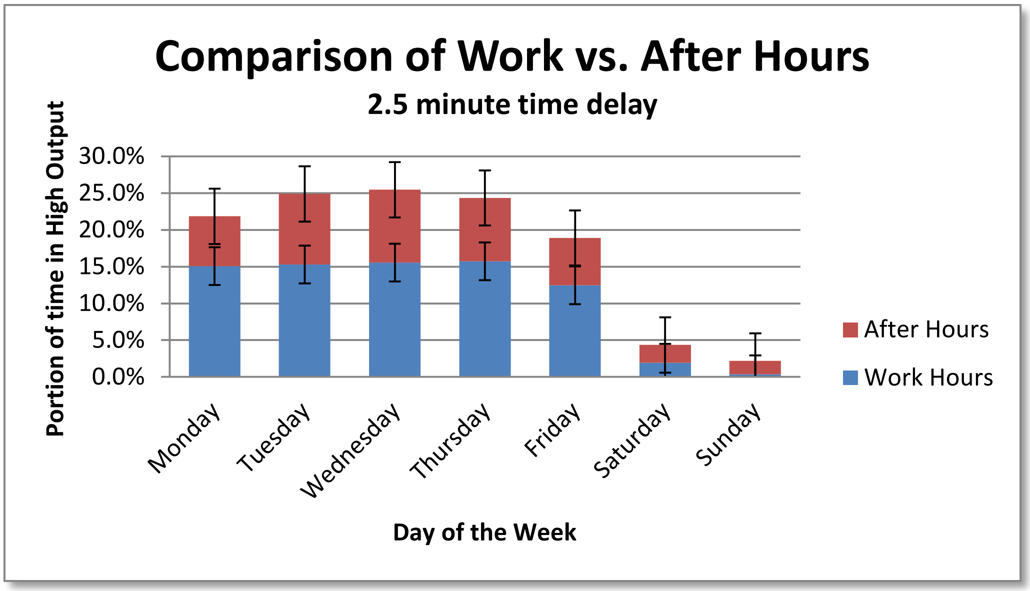


Figure 5.4. Comparison of Operation by Time of Day (2.5-Minute Time Setting)

5.2.4 Location of Luminaires

The physical location of a given luminaire relative to traffic or pedestrian flow also greatly affects the resulting energy use. The California Public Utilities Commission recently showed, via multiple simulations, that economic feasibility of individual sensor installation varies as a function of the specific sensor location within the structure and related traffic flow (CPUC 2011). Occupancy sensors located near a facility's entrance/exit, for example, may see enough activity to render them effectively useless (essentially operating in scenario 1b, as described in section 4.1).

5.2.5 Estimation Based on Sufficient Sample

The noted anomalous behavior that was reported for several of the luminaires underscores the importance of monitoring multiple luminaires over multiple days and across different seasonal periods. Enough data was collected in this instance to indicate that whatever problems or issues have been observed, they are apparently only temporary and their effects are averaged over the longer monitoring periods. In contrast, a monitoring effort involving only a few luminaires spanning perhaps only a one week or few weeks might easily overemphasize the influence of such behavior.

5.3 Cost Effectiveness

A major determinant in cost effectiveness of this installation is the cumulative effect of various factors that promote or hinder the realization of the sensor system's full capabilities. As discussed, these can include the time delay setting, the location of the luminaire relative to traffic flow, level of activity in the area (which is in turn influenced by other factors), and a host of possible issues that effectively "leave savings on the table."

Using 2010 prices, Figure 5.5 depicts the different payback scenarios as a function of both reductions in power use from high to low states and the time splits realized between these during actual operation. Again, both of these are visibly important to maximizing savings, but only the first (power setting in low state) is entirely under the control of the user.

Although some of the factors contributing to the measured time splits are user-controllable, others are not. The controlled variable demonstrated in this study was the adjustment of the time delay from 10 minutes to 2.5 minutes, which correspondingly reduced the time the LED luminaire spent in high state operation from 47% to only 17%. This measure was accomplished at virtually no cost, other than a few minutes of labor to make the adjustments.

Note that traffic flow in this particular installation tends to be somewhat predictable and consistent throughout the year, but is often much less so in other locations. Garages open to the public on a 24-hour basis, for example, may see random activity at virtually any hour. However, even those locations may have additional means of control at their disposal that can be of relatively low cost. Restricting the flow of traffic in select locations (e.g., closing individual floors to new entry) during low-use periods is one such approach.

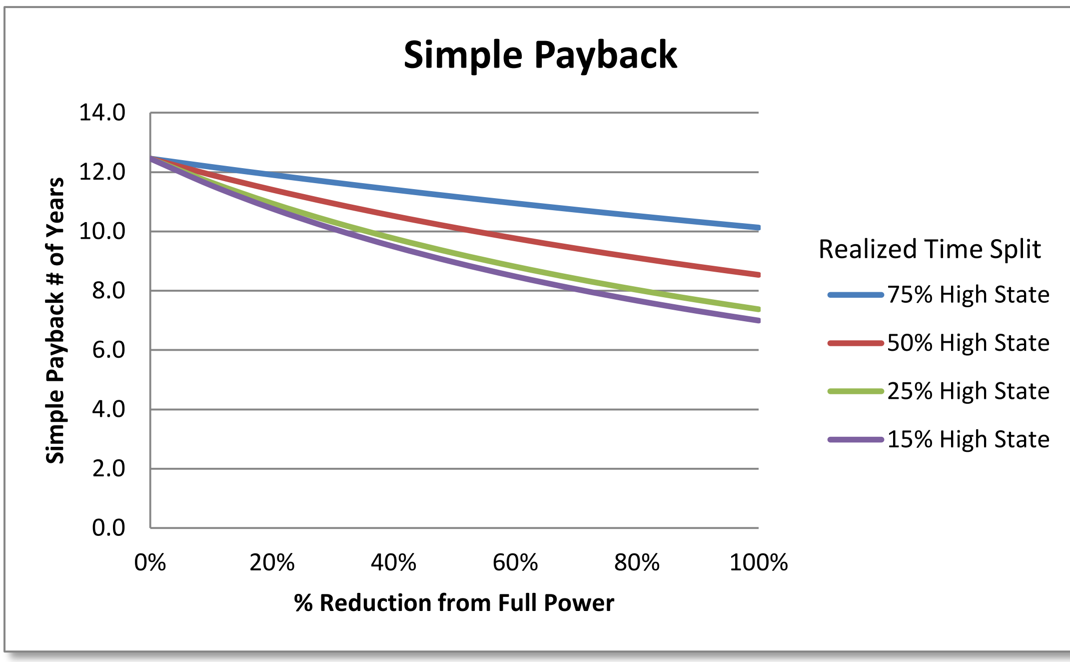


Figure 5.5. Simple Payback as a Function of Low-State Power Setting and Realized Time Split

Finally, any faulty operation of the system is of concern, not only for energy use but also for safety and security. Focusing on energy use, the luminaires that were exhibiting false tripping behavior substantially reduced the energy savings achieved by their respective occupancy sensors during the periods this behavior was in effect. The worst of these essentially operates in scenario 1b during these times, as it virtually never drops into the low state during these periods. Fortunately, overall impacts were minimal.

6.0 Conclusions

Because occupancy sensors are still a relatively recent addition to the parking facility lighting market, growing pains are expected and lessons learned will accompany their early use. Nonetheless, this particular installation encountered relatively few challenges while offering nearly ideal conditions for a combined LED/occupancy sensor approach. Adequate coverage of the sensors and consequent response of the lighting system to garage activity enabled this site to push the envelope in terms of both maximizing the power reduction between high and low states and setting a time delay that was just long enough to avoid inconveniencing occupants while minimizing unnecessary energy use. The use of occupancy sensors at this site produced substantial energy savings and a highly regarded installation, while successfully demonstrating the incremental levels of savings available from different control settings.

Varying characteristics of users and ambient environments may mean that the greatest success will come from detection equipment and deployment strategies that have been specifically designed for the particular application, and perhaps even customized on site in terms of operation. Done correctly, it is abundantly clear that the combination of occupancy detection and bi-level dimming systems with efficient lighting equipment can significantly increase energy savings.

At the same time, it must also be recognized that the potential energy and cost savings are finite. Different approaches to achieving them often compete with one another in a form of zero sum game. Upgrading to a higher efficacy luminaire, for example, means that less energy use is subsequently available to generate savings by adding a control system. The diminishing returns visible in Figure 5.1 are a direct result of this phenomenon; in this installation, the largest magnitude of energy saved came from the initial substitution of the LED product for the HPS system. Adding the occupancy sensor at the initial factory settings achieved a similar percentage reduction in energy use, but the actual magnitude of those savings were reduced by savings that had already been claimed by the LED substitution. Note also that such effective use of controls is contingent on the accompanying use of non-HID equipment.

Finally, making the most of an occupancy sensor-based system is a balancing act between numerous elements. Some of these are user- or site-based, but others are technology- or manufacturer-based. Careful attention must be given to all of these issues to maximize the performance and savings achieved from the investment.

7.0 References

BLS - U.S. Department of Labor, Bureau of Labor Statistics. 2012. *Occupational Outlook Handbook, 2012-13 Edition, Construction Laborers and Helpers*. Accessed January 27, 2013 at http://www.bls.gov/ooh/construction-and-extraction/construction-laborers-and-helpers.htm (last updated March 29, 2012).

CPUC - California Public Utilities Commission. 2011. *Parking Garage Lighting and Controls, 2013 California Building Energy Efficiency Standards*. Sacramento, CA.

Executive Order 13423. "Strengthening Federal Environmental, Energy, and Transportation Management." 72 FR 3919-3923. *Federal Register*, January 26, 2007. Accessed March 25, 2013 at http://www.gpo.gov/fdsys/pkg/FR-2007-01-26/pdf/07-374.pdf.

IES RP-20-98. *Lighting for Parking Facilities*. Illuminating Engineering Society, New York, NY.

IES RP-6-01. *Sports and Recreational Lighting*. Illuminating Engineering Society, New York, NY.

Next Generation Luminaires. 2013. *Best in Class – Parking Garage, "VizorLED" by Philips Wide-Lite*. Accessed March 26, 2013 at http://www.ngldc.org/09/winners/bestinclass_VizorLED.stm (last updated March 2013).

Philips - Philips Wide-Lite Professional Luminaires. 2012. *VZ24-60G2 Series, VizorLED Parking & Under Canopy Series G2*. San Marcos, TX. Accessed March 25, 2013 at http://www.widelite.com/sites/default/files/VZ24-60G2-WLSP0393E0912_Form_0.pdf .

Appendix A

Product Cutsheets

Appendix A – LED Product Cutsheet

VZ Series

VizorLED Parking & Under Canopy Luminaire

VizorLED LED SOLUTIONS

Type:	Job:	Approvals:

Catalog Number:

Series/Size	# of LEDs	Distribution	Voltage	Mounting	Options (Factory Installed)	Finish	Accessories (Field Installed)
						- ASA	

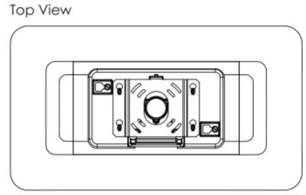
Date:

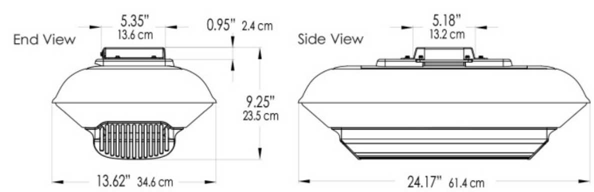
Overall Dimensions *For Reference Only*

VZ24

EZ Hanger Plate Mount
(standard mounting)
(mounts to standard 4" square or octagonal j-boxes)

Weight: 28 lbs. (12.7 kg)

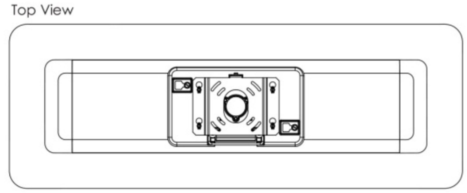


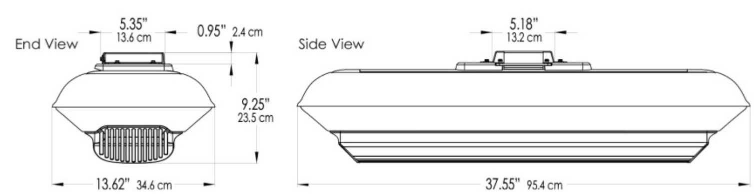


VZ38

EZ Hanger Plate Mount
(standard mounting)
(mounts to standard 4" square or octagonal j-boxes)

Weight: 42 lbs. (19.1 kg)





Specifications

Rated Life
60,000 hours.

Construction
Heavy duty extruded heatsink, 6063-T5, optimally engineered / designed via fin length and fin spacing to achieve thermal resistance < 0.18°C per watt. Two die-cast endcaps, 380 alloy. Thermoformed canopy top transition housing. Extruded main top housing driver heatsink, 6063-T5. Standard unit constructed to IP65.

Non-Direct View™ (NDV™) LED Optics
Faceted MIRO reflector (minimum 94% reflectivity). Designed around Lumiled Rebel LED light source.

Driver
High power factor (>90% standard, >86% dimming). Constant current: 350mA and 700mA. Voltage: 120-277. Temperature range: -30°C (-22°F) to 50°C (122°F). Open / short circuit protection. Optional 0-10V pulse width modulation dimming down to 10% power. Off-state power consumption is 0.0 watts. RoHS compliant.

LED and Board Array
Lumiled Rebel. LED only: 100 lumens per watt, System only: 47-65 lumens per watt. See technical data for details. Color temperature: 4125K +/- 175K. Aluminum metal clad board. Thermal resistance (Board to Heatsink): <0.5°C per watt. RoHS compliant.

Mounting
Heavy duty top casting, 380 alloy. Standard mounting shall include a galvanized steel Easy Hanger Plate, (Bulk Pack available). Alternately, unit may be pendant mounted to rigid conduit (by others), yoke mounted or specified with a through-wire provision.

Finish
Standard finish of die cast endcaps and extruded main top housing driver heatsink shall be Textured Satin Aluminum. Extruded (finned) heatsink has a clear anodized finish. Thermoformed canopy top transition has an embedded matte Satin Aluminum finish.

Colored Lens Option
Colored lenses may be specified for parking level or drive lane identification.

Chromed End Cap Option
As a decorative option, the end caps may be chromed.

Proximo™ Occupancy Detector
Option may be specified for additional energy savings during unoccupied periods. Standard dim level factory set to 10%.

Cradle to Cradle Recycling
To minimize environmental impact at end of product life cycle, the C2C product recycling assistance program is available.

Listings
ETL Listed luminaire, IP65 rated (IP52 w/ Proximo), UL 1598 suitable for Wet Locations. The quality systems of this facility have been registered by UL to the ISO 9001 Series Standards.

Warranty / Terms and Conditions
Standard 5 Year Limited Warranty

Wide-Lite's current Warranty may be found at www.wide-lite.com (keyword: warranty) as well as current Standard Terms and Conditions of Sale (keyword: terms).

All sales of items in this catalogue shall be subject to Wide-Lite's Standard Terms and Conditions of Sale current at the time of shipment. If you do not have a copy of Wide-Lite's Warranty and Standard Terms, please contact the factory for same prior to ordering.

Philips Wide-Lite reserves the right to change specifications and dimensions without notice. Lamp and electrical specifications / availability subject to change by manufacturer without notice. Please refer to detailed specification sheets for additional information and spec details.

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Bulletin No. WLSP0277G0310

PHILIPS WideLite

VZ Series

VizorLED Parking & Under Canopy Luminaire

VizorLED

Type:	Job:	Page 2 of 6

(view from drive lane)

LIGHTFAIR INTERNATIONAL 2009 — WINNER INNOVATION AWARDS BEST OF CATEGORY 2009 — ROADWAY, SPORTS, OUTDOOR ARCHITECTURAL, SITE LIGHTING

NGL2009 DOE & IESNA BEST IN CLASS 2009

Series/Size	# of LEDs	Distribution	Voltage	Mounting	Options	Finish
❒ **VZ24**	❒ **30** ❒ **60**	❒ **B** Bi-Axial Symmetric ❒ **D** Downlight *(see polar curves below for details)*	❒ **120** ❒ **208** ❒ **240** ❒ **277**	❒ **EZ** Easy Hanger Plate *(standard)* ❒ **EZBP** Bulk Pack Easy Hanger Plate ❒ **PND-RC** Pendant Mount *(to Rigid Conduit)* ❒ **PND-RC-24LDS** Pendant Mount with 24" leads ❒ **TW2** Thru-wire Provision ❒ **Y** Yoke Mount	❒ **F1** Single Fuse (120/277V) ❒ **F2** Double Fuse (208/240V) ❒ **CL(XX)** [1] Colored Drive Lane Lenses (XX) = RD - red, BL - blue, YL - yellow, OR - orange, PP - purple, PK - pink, GR - green ❒ **CE** Chromed End Caps ❒ **DD** Dimming Driver ❒ **PX10** [2,3] Proximo™ Occupancy Detector ('DD' included)	☑ **ASA** Anodized Satin Aluminum
❒ **VZ38**	❒ **50** ❒ **100**					

Notes:
1) Contact factory for additional color options.
2) Proximo standard dimming level set to 10%. Can be field programmable (20-90%). Includes 'DD' dimming driver standard.
3) VizorLED is currently rated IP52 when used with Proximo.

Accessories (Ordered Separately)

❒ **F1-KIT** Single Inline Fuse Kit (120/277V)
❒ **F2-KIT** Double Inline Fuse Kit (208/240V)
❒ **C2C** Cradle to Cradle Product Recycling Assistance Program

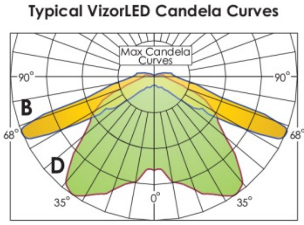
Technical Data

(Based on standard driver, 'B' distribution, Rated Life 60,000 hrs. 4125K +/- 175K CCT standard, contact factory for additional CCTs)

	100 LED VZ38 Unit[4]	50 LED VZ38 Unit	60 LED VZ24 Unit[4]	30 LED VZ24 Unit
Total System Watts	113W[5]	124W[5]	68W[5]	74W[5]
Initial Lumens @ 25°C Ambient	7230 @ 350mA	6272 @ 700mA	4411 @ 350mA	3730 @ 700mA
Lumens per Watt @ 25°C Ambient	64	51	65	50
Initial Lumens @ 40°C Ambient	6898 @ 350mA	5947 @ 700mA	4271 @ 350mA	3568 @ 700mA
Lumens per Watt @ 40°C Ambient	61	48	62	48
Initial Lumens @ 50°C Ambient	6739 @ 350mA	5848 @ 700mA	4178 @ 350mA	3490 @ 700mA
Lumens per Watt @ 50°C Ambient	61	47	61	47

Notes: 4) Baseline independant LM-79 reports available for VZ38-100-B&D and VZ24-60-B&D configurations for performance verification. All other reports are tested in-house per LM-79 guidelines and calibrated to baseline tested standards.
5) Due to LED forward voltage variations and driver efficiency, total system watts could vary +/-8%.

Typical VizorLED Candela Curves



Note: Provides up to 5% Uplight

Philips Wide-Lite reserves the right to change specifications and dimensions without notice. Lamp and electrical specifications / availability subject to change by manufacturer without notice. Please refer to detailed specification sheets for additional information and spec details.

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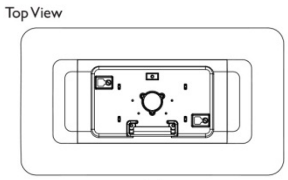
Bulletin No. WLSP0277G0310

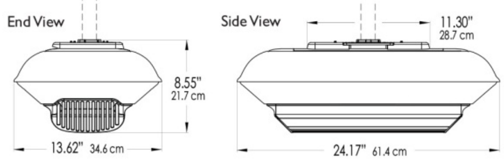
PHILIPS WideLite

Mounting Option details

Pendant Mount
VZ24

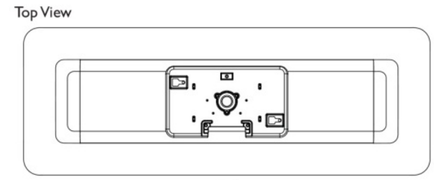
pendant by others
3/4" NPT required

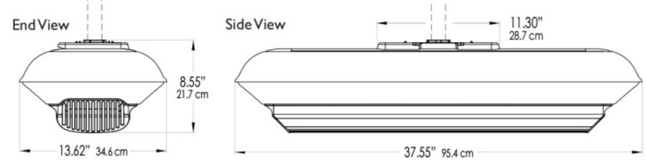




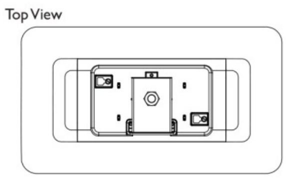
Pendant Mount
VZ38

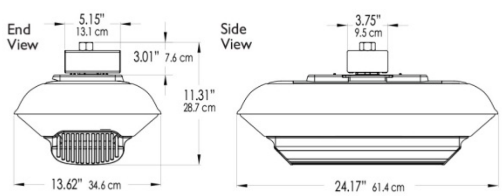
pendant by others
3/4" NPT required



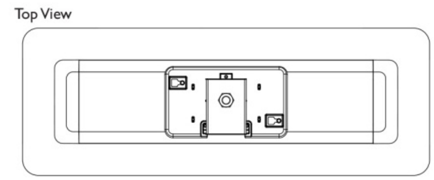


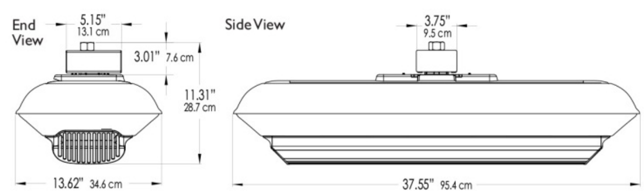
Thru-Wire Provision
VZ24





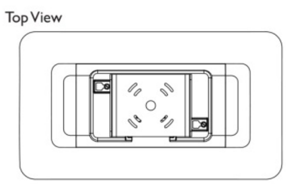
Thru-Wire Provision
VZ38

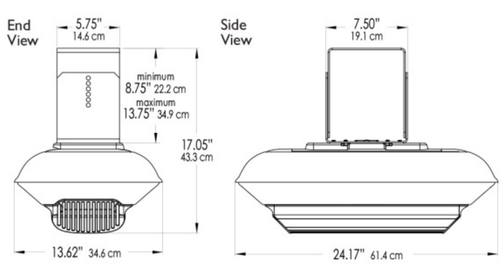




Yoke Mount
VZ24

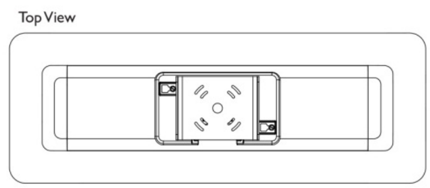
(mounts to standard 4" square or octagonal j-boxes)

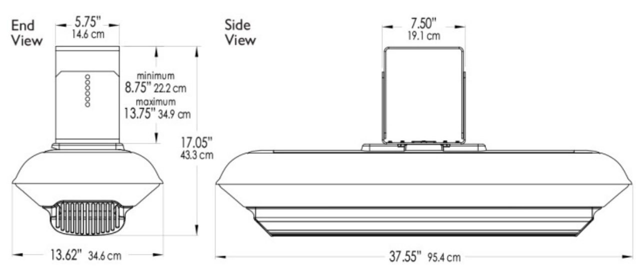




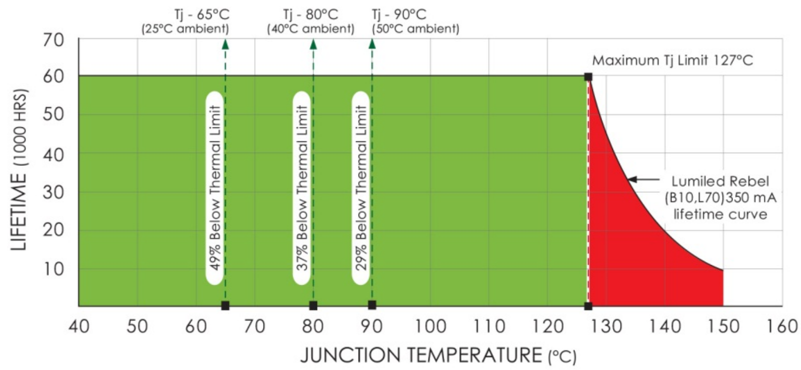
Yoke Mount
VZ38

(mounts to standard 4" square or octagonal j-boxes)





Measured Junction Temperatures (Tj)
VZ38 100 LED Unit & VZ24 60 LED Unit (350mA)



Green shaded portion represents junction temperatures below LED manufacturer's recommended limit to ensure a minimum of 60,000 hours of rated life.

Potential Life Expectancy Table Above the 60,000 Rated LED Life at Multiple Ambient Temperatures
VZ38 100 LED Unit & VZ24 60 LED Unit (350mA)

Note: LED rated life per the B10,L70 curve is 60,000 hrs. The tables below showing potential LED life expectency are based on VizorLED's superior thermal management, actual junction temperature (Tj) and projected B10,L70 curves. The projected life in years may be extended even further if used with "DD" or "PX" dimming options.

VZ38 100 LED (350mA)

AVERAGE OUTDOOR AMBIENT TEMP	FIXTURE JUNCTION TEMP (Tj)	POTENTIAL LED LIFE EXPECTANCY B10, L70 (hrs)	FIXTURE EFFICACY (lumens / watt)	POTENTIAL LED LIFE EXPECTANCY @ 10 HRS/DAY (yrs)	POTENTIAL LED LIFE EXPECTANCY @ 24 HRS/DAY (yrs)
-30°C / -22°F	10°C	304,600	72	83.4	34.8
-20°C / -4°F	20°C	277,600	70	76.0	31.7
-10°C / 14°F	30°C	250,600	69	68.6	28.6
0°C / 32°F	40°C	223,600	67	61.3	25.5
10°C / 50°F	50°C	196,600	66	53.9	22.4
25°C / 77°F	65°C	156,600	64	42.8	17.8
30°C / 86°F	70°C	142,600	63	39.1	16.3
40°C / 104°F	80°C	115,600	61	31.7	13.2
50°C / 122°F	90°C	88,600	60	24.3	10.1

VZ24 60 LED (350mA)

AVERAGE OUTDOOR AMBIENT TEMP	FIXTURE JUNCTION TEMP (Tj)	POTENTIAL LED LIFE EXPECTANCY B10, L70 (hrs)	FIXTURE EFFICACY (lumens / watt)	POTENTIAL LED LIFE EXPECTANCY @ 10 HRS/DAY (yrs)	POTENTIAL LED LIFE EXPECTANCY @ 24 HRS/DAY (yrs)
-30°C / -22°F	10°C	304,600	74	83.4	34.8
-20°C / -4°F	20°C	277,600	73	76.0	31.7
-10°C / 14°F	30°C	250,600	71	68.6	28.6
0°C / 32°F	40°C	223,600	69	61.3	25.5
10°C / 50°F	50°C	196,600	68	53.9	22.4
25°C / 77°F	65°C	156,600	65	42.8	17.8
30°C / 86°F	70°C	142,600	64	39.1	16.3
40°C / 104°F	80°C	115,600	62	31.7	13.2
50°C / 122°F	90°C	88,600	61	24.3	10.1

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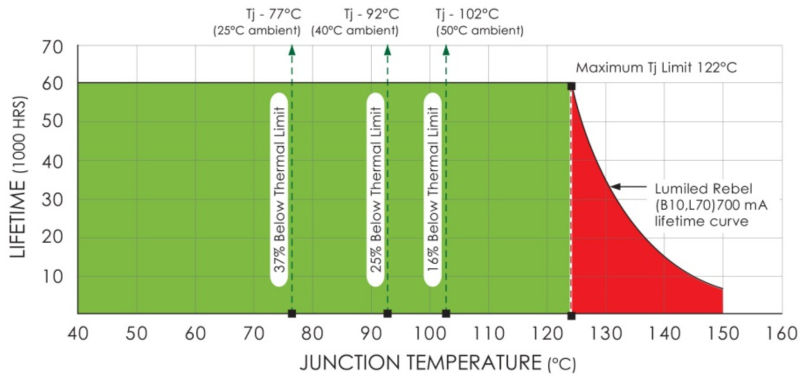
Measured Junction Temperatures (Tj)
VZ38 50 LED Unit & VZ24 30 LED Unit (700mA)



Green shaded portion represents junction temperatures below LED manufacturer's recommended limit to ensure a minimum of 60,000 hours of rated life.

Potential Life Expectancy Table Above the 60,000 Rated LED Life at Multiple Ambient Temperatures
VZ38 50 LED Unit & VZ24 30 LED Unit (700mA)

Note: LED rated life per the B10,L70 curve is 60,000 hrs. The tables below showing potential LED life expectency are based on VizorLED's superior thermal management, actual junction temperature (Tj) and projected B10,L70 curves. The projected life in years may be extended even further if used with "DD" or "PX" dimming options.

VZ38 50 LED (700mA)

AVERAGE OUTDOOR AMBIENT TEMP	FIXTURE JUNCTION TEMP (Tj)	POTENTIAL LED LIFE EXPECTANCY B10, L70 (hrs)	FIXTURE EFFICACY (lumens / watt)	POTENTIAL LED LIFE EXPECTANCY @ 10 HRS/DAY (yrs)	POTENTIAL LED LIFE EXPECTANCY @ 24 HRS/DAY (yrs)
-30°C / -22°F	22°C	304,600	56	83.4	34.8
-20°C / -4°F	32°C	277,600	55	76.0	31.7
-10°C / 14°F	42°C	250,600	54	68.6	28.6
0°C / 32°F	52°C	223,600	53	61.3	25.5
10°C / 50°F	62°C	196,600	52	53.9	22.4
25°C / 77°F	77°C	156,600	51	42.8	17.8
30°C / 86°F	82°C	142,600	50	39.1	16.3
40°C / 104°F	92°C	115,600	48	31.7	13.2
50°C / 122°F	102°C	88,600	47	24.3	10.1

VZ24 30 LED (700mA)

AVERAGE OUTDOOR AMBIENT TEMP	FIXTURE JUNCTION TEMP (Tj)	POTENTIAL LED LIFE EXPECTANCY B10, L70 (hrs)	FIXTURE EFFICACY (lumens / watt)	POTENTIAL LED LIFE EXPECTANCY @ 10 HRS/DAY (yrs)	POTENTIAL LED LIFE EXPECTANCY @ 24 HRS/DAY (yrs)
-30°C / -22°F	22°C	304,600	57	83.4	34.8
-20°C / -4°F	32°C	277,600	56	76.0	31.7
-10°C / 14°F	42°C	250,600	55	68.6	28.6
0°C / 32°F	52°C	223,600	53	61.3	25.5
10°C / 50°F	62°C	196,600	52	53.9	22.4
25°C / 77°F	77°C	156,600	50	42.8	17.8
30°C / 86°F	82°C	142,600	49	39.1	16.3
40°C / 104°F	92°C	115,600	48	31.7	13.2
50°C / 122°F	102°C	88,600	47	24.3	10.1

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Bulletin No. WLSP0277G0310

Option details (Factory Installed)

F1 Single Fuse (120/277V)

F2 Double Fuse (208/240V)

Consists of 1 or 2 fuse holders and 1 or 2 KTK/KLK 30 amp fuses.

CL(XX) Colored Drive Lane Lenses

XX = color of lens:

- **RD** red
- **BL** blue
- **YL** yellow
- **OR** orange
- **PP** purple
- **PK** pink
- **GR** green

Contact factory for additional color options.

CE Chromed End Caps

Decorative option adds distinctive high-end polish at drive lane view.

DD Dimming Driver (0-10V)

Continuous dimming down to 10% power.

Useful for building management systems to accomplish load shedding during peak energy consumption periods.

PX10 Proximo™ Occupancy Detector

Proximo standard dimming level set to 10%. Can be field programmable (20-90%). Includes 'DD' dimming driver standard.

Accessory details (Shipped Separately)

F1-KIT Single Fuse Kit (120/277V)

F2-Kit Double Fuse Kit (208/240V)

cradle to cradle

reduce renew recycle

C2C Cradle to Cradle Product Recycling Assistance Program

Reduces environmental impact at product end-of-life. The C2C program allows the customer to return the product to Wide-Lite for recycling or disposal within current environmental guidelines.

Notes

LIGHTFAIR INTERNATIONAL The future. Illuminated. 2009

WINNER INNOVATION AWARDS BEST OF CATEGORY 2009

ROADWAY, SPORTS, OUTDOOR ARCHITECTURAL, SITE LIGHTING

NGL2009 DOE & IESNA BEST IN CLASS 2009

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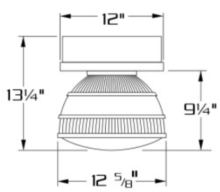
Bulletin No. WLSP0277G0310

PHILIPS WideLite

Appendix A – HPS Product Cutsheet

PSL12S

(175 WATT MAX.)



SPECIFICATIONS:

LUMINAIRE: CORROSION RESISTANT, DURABLE PRECISION CAST ALUMINUM CONSTRUCTION.

OPTICS: INJECTION MOLDED, UV STABILIZED ACRYLIC PRISMATIC REFRACTOR PROVIDES WIDE LATERAL DOWN LIGHT DISTRIBUTION ALONG WITH UPLIGHT FOR UNIFORM CEILING ILLUMINATION. PRECISELY POSITIONED SHIELD REDUCES DIRECT GLARE. CLEAR CONVEX ACRYLIC LENS IS MECHANICALLY FASTENED TO REFRACTOR WITH STAINLESS STEEL TRIM RING.

LAMP HOLDER: MEDIUM BASE PORCELAIN.

LAMP: (BY OTHERS)

BALLAST: H.P.F./C.W.A. AUTOTRANSFORMER, -20° STARTING TEMPERATURE. ELECTRICAL COMPONENTS ARE MOUNTED TO A REMOVABLE BALLAST TRAY. BALLAST IS EQUIPPED WITH FACTORY INSTALLED QUICK DISCONNECT PLUG.

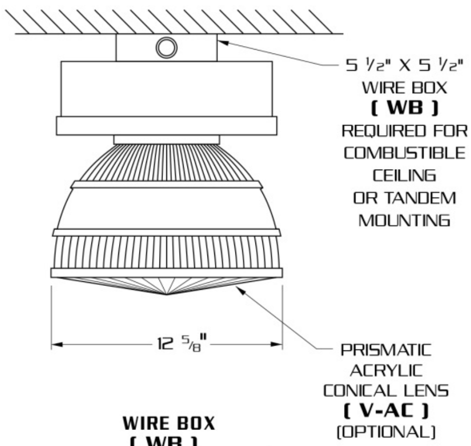
FINISH: POLYESTER POWDER COAT-STATE OF THE ART 20 PSI PRESSURE POWER WASH AT 140° TEMPERATURE INCORPORATES FOUR STEP IRON PHOSPHATE PROCESS TO CLEANSE AND PRETREAT THE METAL SURFACE FOR MAXIMUM PAINT ADHESION. ELECTROSTATICALLY APPLIED TEXTURED POLYESTER POWDER TOPCOAT IS BAKED AT 400° TEMPERATURE FOR MAXIMUM HARDNESS AND EXTERIOR DURABILITY.

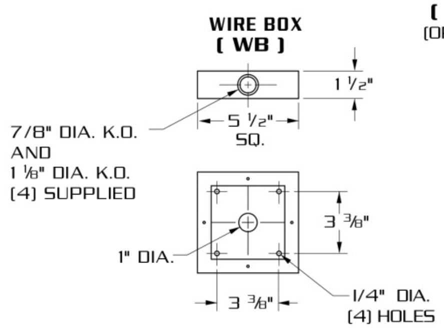
U.L. Listed for wet location

U.S. ARCHITECTURAL LIGHTING

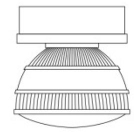
660 WEST AVENUE O, PALMDALE, CA. 93551
(661) 233-2000
FAX NO. (661) 233-2001
www.usaltg.com

E1-3





LAMP SIZE:
35 - 175 WATT



PRECISION CAST ALUMINUM HOUSING

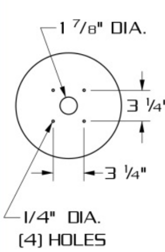
WIDE LATERAL DOWNLIGHT DISTRIBUTION

UNIFORM UPLIGHT

IMPROVED DRIVER VISIBILITY

ORDERING INFORMATION

MODEL NO. : PSL12S	OPTICS	WATTAGE TYPE VOLTAGE	MOUNTING	FINISH	OPTIONS

MODEL NO. :	OPTICS	LAMP	MOUNTING	FINISH	OPTIONS
P S L 1 2 S	**STANDARD:** ☐ CLEAR PRISMATIC ACRYLIC REFRACTOR WITH SMOOTH DOME ACRYLIC LENS TYPE V........**V-AD** **OPTIONS:** ☐ CLEAR PRISMATIC POLYCARBONATE REFRACTOR WITH SMOOTH DOME POLYCARBONATE LENS TYPE V........**V-PD** ☐ CLEAR PRISMATIC ACRYLIC REFRACTOR WITH PRISMATIC ACRYLIC CONICAL LENS TYPE V........**V-AC**	**WATTAGE TYPE VOLTAGE** ☐ **175** ☐ **HPS** ☐ **120** ☐ **150** ☐ **MH** ☐ **208** ☐ **100** ☐ **MV** ☐ **240** ☐ **70** ☐ **277** ☐ **50** ☐ **480** ☐ **35** ☐ **MT**	☐ **CSM** .... 	**STANDARD TEXTURED FINISH** ☐ BLACK **RAL-9005-T** ☐ WHITE **RAL-9003-T** ☐ GREY **RAL-7004-T** ☐ DRK BRONZE **RAL-8019-T** ☐ GREEN **RAL-6005-T** FOR SMOOTH FINISH REMOVE SUFFIX "T" (EXAMPLE: RAL-9500) SEE WEBSITE FOR ADDITIONAL COLORS	☐ 1 1/2"X5 1/2"X5 1/2" WIRE BOX . . . .**WB** ☐ SINGLE FUSED (120V. , 277V) . . . .**SF** ☐ DOUBLE FUSE (208V. , 240V) . . . .**DF** ☐ QUARTZ RESTRIKE . . . .**QTZ** ☐ 3/8" IPS STEM MOUNT AND SWIVEL CANOPY (4'-0" MAX.). . . . .**SM** ☐ OPEN BOTTOM . . . . **OB**

U.S. ARCHITECTURAL LIGHTING
660 WEST AVENUE O, PALMDALE, CA. 93551
(661) 233-2000
FAX NO. (661) 233-2001
www.usaltg.com

Appendix B

Energy Use Profile of Occupancy Sensor System

Appendix B – Energy Use Profile of Occupancy Sensor System

The following tables display the daily (24-hr) average operation of all 10 metered luminaires in terms of the percentage of time spent in high state, by day of the week, for the periods they were monitored. The garage lighting is never turned off, so the luminaires operated in low state during the remaining percentages of each day.

B.1 Average Operation in High State Long Time Delay– Metered Data

As delivered from the manufacturer, the occupancy sensors are set to drop into low state following 10 minutes of no detected activity. At this setting, Table B.1 shows that most luminaires are spending more than half a typical 24-hour weekday operating in high state.

Table B.1. Daily Average Operation in High State at 10-Minute Delay Setting

Week Ending	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
4/3/11	---	---	---	---	---	---	14.0%
4/10/11	54.7%	59.5%	52.6%	61.4%	60.1%	10.7%	12.3%
4/17/11	57.5%	59.0%	59.4%	58.1%	---	---	---
5/22/11	---	---	67.9%	61.3%	58.9%	8.1%	11.8%
5/29/11	66.3%	69.0%	71.5%	71.7%	57.3%	16.5%	25.3%
6/5/11	26.1%[a]	62.8%	74.6%	63.0%	54.3%	12.5%	10.8%
6/12/11	60.9%	65.8%	72.7%	75.3%	70.3%	---	---
7/17/11	---	---	---	---	---	16.2%	8.7%
7/24/11	51.3%	61.5%	60.9%	62.8%	60.6%	21.6%	24.1%
7/31/11	58.1%	56.8%	57.8%	55.3%	57.2%	17.2%	9.6%
8/7/11	48.5%	57.8%	60.3%	68.7%	52.3%	20.7%	23.5%
8/14/11	55.9%	57.8%	55.2%	55.4%	45.2%	---	---
9/4/11	---	---	---	---	---	15.4%	19.8%
9/11/11	23.6%[b]	53.0%	62.7%	59.6%	60.2%	25.6%	7.5%
9/18/11	52.2%	56.6%	56.0%	59.3%	49.0%	1.5%	5.8%
9/25/11	52.5%	57.8%	56.9%	61.5%	61.9%	---	---

(a) Memorial Day 2011 – Federal holiday
(b) Labor Day 2011 – Federal holiday

Table B.2 summarizes the 10-minute delay data into weekday, weekend, and entire week averages.

Table B.2. Summary of Operation in High State at 10-Minute Delay Setting

Week Ending	Weekday	Weekend	Weekly Average
4/3/11	---	Incomplete [a]	Incomplete
4/10/11	62.8%	25.7%	52.2%
4/17/11	63.6%	---	63.6%
5/22/11	64.2%	22.3%	47.4%
5/29/11	65.4%	31.1%	55.6%
6/5/11	57.1%	23.9%	47.6%
6/12/11	66.9%	---	66.9%
7/17/11	---	12.4%	---
7/24/11	59.4%	22.8%	49.0%
7/31/11	57.0%	13.4%	44.6%
8/7/11	57.5%	22.1%	47.4%
8/14/11	53.9%	---	53.9%

(a) Sufficient sample size was not available to average the results for time period.

B.2 Average Operation in High State Short Time Delay – Metered Data

During this study, the occupancy sensor time delay was reduced from 10 minutes to 2.5 minutes. Table B.3 shows the dramatic impact on time spent in high state, by day of the week, during the ensuing monitoring periods.

Table B.3. Daily Average Operation in High State at 2.5-Minute Delay Setting

Week Ending	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
12/11/11						9.5%	3.4%
12/18/11	25.5%	26.6%	30.6%	27.5%	23.2%	1.57%	2.63%
12/25/11	23.42%	28.68%	30.49%	25.60%	12.49%	10.68%	1.80%
1/1/12	3.04%[a]	12.10%	12.01%	12.13%	10.05%		
2/19/12	---					2.7%	1.8%
2/26/12	3.7%[b]	25.5%	27.6%	26.3%	23.9%	0.93%	1.72%
3/4/12	24.72%	27.77%	25.83%	27.71%	20.01%	0.73%	1.85%
3/11/12	24.38%	28.67%	26.15%	26.81%	23.75%		

(a) December 26 – Federal observance of Christmas
(b) President’s Day 2010 – Federal holiday

Table B.4 summarizes the 2.5-minute delay data into weekday, weekend, and entire week averages.

Table B.4. Summary of Operation in High State at 2.5-Minute Delay Setting

Week Ending	Weekday	Weekend	Weekly Average
12/11/11	---	6.4%	6.4%
12/18/11	26.7%	2.1%	19.6%
12/25/11	24.1%	6.2%	19.0%
1/1/12	9.9%	---	---
2/19/12	---	2.3%	2.3%
2/26/12	21.4%	1.3%	15.7%
3/4/12	25.2%	1.3%	18.4%
3/11/12	26.0%	---	---

Appendix C

Utility Tariffs

Appendix C – Utility Tariffs

A PHI Company

DISTRICT OF COLUMBIA
GENERAL SERVICE PRIMARY SERVICE
SCHEDULE GS3A
UPDATED OCTOBER 12, 2012

	Billing Months of June – October (Summer)	Billing Months of November – May (Winter)
Generation[1]		
First 6,000 kwh	$ 0.11772 per kwh	$ 0.11772 per kwh
Additional kwh	$ 0.11772 per kwh	$ 0.11772 per kwh
First 25 kw	No charge	No charge
Additional kw	$ 0.00000 per kw	$ 0.00000 per kw
Procurement Cost Adjustment	**www.pepco.com for monthly rate**	
Transmission[2]		
All kwh	$ 0.00447 per kwh	$ 0.00447 per kwh
Distribution[3]		
Customer Charge	$ 15.69 per month	$15.69 per month
All kwh	$ 0.03424 per kwh	$ 0.02580 per kwh
All kw	$ 5.02 per kw	$ 4.99 per kw
Delivery Tax [4]	$ 0.0077 per kwh	$ 0.0077 per kwh
Public Space Occupancy Surcharge [5]	$ 0.00194 per kwh	$ 0.00194 per kwh
Administrative Credit	**www.pepco.com for monthly rate**	
Sustainable Energy Trust Fund [6]	$ 0. 00150 per kwh	$ 0.00150 per kwh
Energy Assistance Trust Fund [7]	$ 0.0000607 per kwh	$ 0.0000607 per kwh
RAD Surcharge[8]	$ 0.000515 per kwh	$ 0.000515 per kwh
Bill Stabilization Adjustment[9]	**www.pepco.com for monthly rate**	

1 Effective Usage on and after June 1, 2012
2 Effective Usage on and after December 1, 2011
3 Effective Usage on and after October 18, 2012
4 Effective January 1, 2005
5 Effective March 1, 2012
6 Effective October 1, 2010
7 Effective Billing Month of October 2010
8 Effective Service on and after October 1, 2012
9 Effective January 1, 2010

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BUILDING TECHNOLOGIES OFFICE