GATEWAY DEMONSTRATIONS

Application Assessment of Bi-Level LED Parking Lot Lighting

Host Site: Raley's Supermarket, West Sacramento, California

Final Report prepared in support of the
U.S. DOE Solid State Lighting
Technology Demonstration GATEWAY Program

Study Participants:
U.S. Department of Energy
Pacific Gas & Electric
Pacific Northwest National Laboratory
BetaLED
Raley's Supermarket
Energy Solutions

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Emerging Technologies Program

Application Assessment Report #0815

Bi-Level LED Parking Lot Lighting
Raley's Supermarket
West Sacramento, CA

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Preface

Energy Solutions provided monitoring, data collection, and data analysis services for an LED Parking Lot Assessment project under contract to the Emerging Technologies Program of Pacific Gas and Electric Company. The project replaced metal halide (MH) luminaires of nominal 320 watts[1] with new LED luminaires with bi-level operation from BetaLED™.

Acknowledgements

This project was funded by the Emerging Technologies Program of Pacific Gas and Electric Company in collaboration with the Pacific Northwest National Laboratory as part of DOE's SSL GATEWAY Demonstration Program. Energy Solutions would like to gratefully acknowledge the direction and assistance of Pacific Gas and Electric Company, Raley's, Pacific Northwest National Laboratory (representing the United States Department of Energy), and BetaLED for their participation and support of this project.

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[1] The model number and nominal wattage of the baseline MH was not given. Based on measured power and available information, it was assumed that the baseline was a nominal 320 W luminaire.

Executive Summary

This report summarizes an assessment project conducted to evaluate light-emitting diode (LED) luminaires with bi-level operation in an outdoor parking lot application. The project replaced metal halide (MH) fixtures of nominal 320 watts[2] with bi-level LED luminaires from BetaLED equipped with motion sensors. Quantitative light and electrical power measurements were taken to compare base case MH performance with that of the LED replacement luminaires. Economic performance of the LED luminaires as compared to MH was also estimated and qualitative satisfaction with the LEDs was gauged with a customer survey.

The facility selected for this demonstration is a Raley's Supermarket parking lot containing 16 pole-mounted 320-watt MH dropped-lens 'cobrahead'-style luminaires. The demonstration area is approximately one-half of the parking lot. Within the parking aisles are four poles, each with two Type V distribution fixtures. The easternmost poles in the demonstration area each included one flood light directed east toward the store front, in addition to the twin-mount Type V luminaires[3]. The area east of these poles was not included in the illuminance performance evaluation, due to influence by the flood lights.

Each LED luminaire was equipped with a motion sensor, which covered an estimated area of up to 47 feet in diameter at the luminaire mounting height[4]. The motion sensors were set with a time delay feature to reduce the light output from high power to low power operation after approximately 5 minutes of detecting no motion.

A summary of measured electric power results from the study are tabulated in Table ES-1 below for the base case MH luminaires and for LED luminaires on high output, low output, and average demand. Annual savings for electrical energy and cost are estimated based on a customer reported 4,380 annual hours of operation.

The LED luminaires drew an average of 149 watts on high power and 52 watts on low power, compared to the MH luminaires, which drew an average of 346 watts. On average, the LED luminaires were on high power for 55% of the time, and on low power for 45% of the time. This results in a time-averaged demand of 105 watts.

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[2] The model number and nominal wattage of the baseline MH was not given. Based on measured power and available information, it was assumed that the baseline was a nominal 320 W luminaire.

[3] See Appendix C: Monitoring Layout

[4] The installed motion sensor is designed to cover an area of up to 68 feet in diameter when mounted at a height of 40 feet. In this demonstration project, motion sensors were mounted at a height of approximately 29 feet, and are estimated to cover an area of up to 47 feet in diameter based on manufacturer provided information.

Table ES-1: Measured Demand and Potential Energy Savings

	Average Power (W)[5]	Power Savings (W)	Annual Energy Savings (kWh)
MH Luminaire	346	-	-
LED Luminaire (High Power)	149	197 (57%)	863
LED Luminaire (Low Power)	52	294 (85%)	1,288
LED Luminaire (Average)	105	241 (70%)	1,056
Full Parking Lot (Estimate Assuming All Converted to LED)	1,680	3,856	16,889

Photopic and scotopic illuminance[6] measurements were taken on a 9' x 10' grid under MH luminaires, and LED luminaires at both high and low output conditions.[7] The maximum and minimum illuminance values were measured and comparative metrics were calculated including: average illuminance; Coefficient of Variation; Average-to-Minimum Uniformity Ratio; and Maximum-to-Minimum Uniformity Ratio.

The LED luminaire on high output delivered lighting performance that was better than the MH baseline: the average illuminance increased slightly, and the uniformity ratios and the coefficient of variance decreased, both suggesting a more uniform lighting distribution. The LED on low output delivered improved uniformity but lower average illuminance than the MH baseline. This was as expected, and corresponds to time periods when no movement is detected surrounding the luminaire.

The Illuminating Engineering Society of North America (IESNA) recommends maintained illuminance values for parking lots of 0.2 footcandles (fc) for typical (in-use) conditions and 0.5 fc for enhanced security. However, IESNA also states that "during periods of non-use, the illuminance of certain parking facilities may be turned off or reduced to conserve energy. If reduced lighting is to be used only for the purpose of property security, it is desirable that the minimum (low point) value not be less than [0.1 fc]." [8] On low, the LED luminaire output exceeds the IESNA recommendations for typical conditions. When motion is detected the LED luminaire is on high output, and IESNA recommendations for enhanced security are met as well.

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[5] The manufacturer reported power demand of 158 watts at high power and 54 watts at low power for the LED luminaires.

[6] See 'Project Results and Discussion - Lighting Performance' section.

[7] Monitoring layout followed Illuminating Engineering Society of North America guidance for photometric measurements of parking areas (LM-64-01) as closely as possible.

[8] IESNA RP-20-98

Table ES-2: Comparison of Measured Photopic Performance

Luminaire	Average Illuminance (Footcandles)	Minimum Illuminance (Footcandles)	Coefficient Of Variation	Average-to-Minimum Uniformity
MH	1.8	0.5	0.53	3.6 : 1
LED High Power	1.9	0.6	0.33	3.2 : 1
LED Low Power	0.9	0.3	0.32	2.9 : 1

Table ES-3: Comparison of Measured Scotopic Performance

Luminaire	Average Illuminance (Footcandles)	Minimum Illuminance (Footcandles)	Coefficient Of Variation	Average-to-Minimum Uniformity
MH	2.6	0.6	0.54	4.3 : 1
LED High Power	3.5	0.9	0.34	3.8 : 1
LED Low Power	1.5	0.6	0.33	2.7 : 1

In this evaluation, simple payback and net present value were calculated for both retrofit and new construction scenarios based on estimated energy savings and host site maintenance costs. Due to the robust nature of LED technology and uncertainty regarding the useful life to the luminaires, for this economic analysis the LED luminaires were assumed to have zero regular maintenance cost over the course of their useful life.[9]

When maintenance and replacement costs for MH luminaires were combined with energy costs, the bi-level operation LED luminaires cost approximately $278 less per year to operate than a MH luminaire. In a new construction setting, where the LED luminaire is installed in place of a 320-watt MH luminaire, the total incremental cost is $925.83 per luminaire replaced. In a retrofit scenario, the incremental cost is the full cost of the LED luminaire including installation, or $1,300 per luminaire. As a result, the calculated simple payback periods in this application were 3.3 and 4.7 years for the new construction and retrofit scenarios, respectively. The 15-year net present values were approximately $2,660 and $2,290 for the new construction and retrofit scenarios, respectively.

[9] For more information, see 'Economic Performance' section.

Table ES-4: Summary of Economic Performance

Luminaire Type	Initial Investment	Incremental Cost	Annual Savings	Simple Payback (Years)	15-Year NPV
MH (New Construction)	$374.17	-	-	-	-
LED (New Construction)	$1,300.00	$925.83	$277.95	3.3	$2,661
LED (Retrofit)	$1,300.00	$1,300.00	$277.95	4.7	$2,287

Economic performance in this demonstration was sensitive to maintenance savings, as these were the primary contributor to a favorable payback. Since individual sites will have specific characteristics that differ from those here, readers are strongly encouraged to use their own savings estimates. Utility or government incentive programs could further help to encourage adoption of LED luminaires for outdoor parking lot applications by reducing the initial investment required.

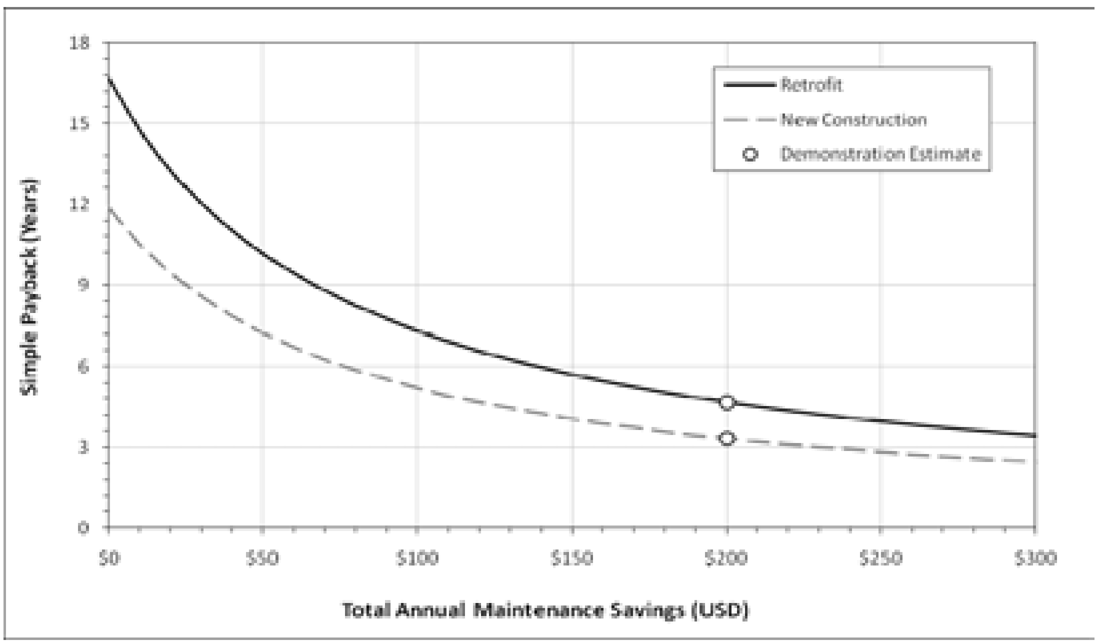

Figure ES-1: Simple Payback Terms for LED Luminaires

In this demonstration, great potential for energy savings was shown by using LED lighting for outdoor parking lots, as compared to lighting with MH luminaires. Even when on 'high' the LED luminaires used significantly less power than the MH luminaires, and these savings were increased by the bi-level operation which allowed them to be on 'low' roughly half of the time. The LED luminaires also demonstrated increased lighting performance relative to the metal halide luminaires while operating on 'high,' while meeting IESNA standards while on 'low.' These quantitatively measured improvements were further supported by very positive user feedback, as gauged by a survey of 17 store employees. On a question regarding appearance of the parking lot, the new lights scored an average 8.8 on a scale from 1 to 10 in comparison with the previous lighting (a score of 5 would be neutral between the two sources; a score of 4 or less would mean the appearance was judged worse). Additionally, although the survey did not specifically attempt to assess security, more than one response independently cited an increased sense of security with the LED lights. Other questions in the survey received similarly positive responses, and it should be noted that these results pertain to a comparison between two "white" light sources.

Project Background

Project Overview

Many parking lot and parking garages in commercial and institutional facilities are currently illuminated with high intensity discharge (HID) lighting sources. Because this type of lighting is not suitable to dimming or frequent switching, this lighting is typically operated the entire evening, even when the parking lot or garage is mostly or completely empty.

The California Lighting Technology Center (CLTC), through its Smart Lighting Initiative, has pursued utilization of high efficiency lighting sources with bi-level motion sensors to reduce lighting levels when the parking area is not in use. This LED Assessment project studied the applicability of this concept by evaluating light-emitting-diode (LED) luminaires with integral motion sensors as replacements for existing parking lot lighting.

Metal halide (MH) luminaires were replaced with new LED luminaires from BetaLED equipped with motion sensors for bi-level operation at a Raleys' Supermarket parking lot located in West Sacramento, California. The potential electrical demand and energy savings were measured in terms of average wattage and estimated annual kWh usage. Lighting performance was measured in terms of illuminance, uniformity, and by the satisfaction and concerns of interested parties. Finally, economic performance was evaluated through simple payback and net present value analyses for substitution of MH luminaires with LED luminaires, in both new installation and retrofit scenarios.

The assessment was conducted as part of the Emerging Technologies Program of Pacific Gas and Electric Company in collaboration with DOE's SSL GATEWAY Demonstration Program. The Emerging Technologies program "is an information-only program that seeks to accelerate the introduction of innovative energy efficient technologies, applications and analytical tools that are not widely adopted in California…. [The] information includes verified energy savings and demand reductions, market potential and market barriers, incremental cost, and the technology's life expectancy."

Technology and Market Overview

The dominant lighting technology for parking areas is high intensity discharge (HID), typically using MH or high-pressure sodium (HPS) lamps. At the time of this assessment however, LEDs are beginning to make inroads in a variety of outdoor applications because of their potential advantages compared to these traditional sources. LEDs have the potential for long life, reduced maintenance, high color rendition, reduced operating cost, and lower energy usage than other technologies. However, the initial cost of LEDs is currently much higher than alternative light sources.

The US Department of Energy (DOE) is currently evaluating applications of LEDs through field demonstration and lab testing programs (such as GATEWAY Technology Demonstration Program and CALiPER[10]) and acknowledges that "LED technology is rapidly becoming competitive with

[10] DOE's SSL GATEWAY Technology Demonstration Programs support demonstrations of high-performance LED products to develop field data and experience for applications that save energy, are cost effective, and maintain or improve light levels. The DOE Commercially Available LED Product Evaluation and Reporting (CALiPER) program supports testing of a wide array of SSL products available for general

high-intensity discharge light sources for outdoor area lighting."[11] The DOE reports the technology is changing at a rapid pace: overall, the performance of LED luminaires is advancing in light output per chip at a rate of approximately 35% annually, with costs decreasing at a rate of 20% annually.[12]

A report by Navigant Consulting in 2002 estimates that lighting makes up approximately 22% of IOU kWh sales on a national scale. The study further estimates that lighting for parking accounts for roughly 4% of kWh sales for lighting.[13] Using kWh sales figures from a 2006 study, [14] the total consumption in PG&E's service territory for lighting is calculated to be on the order of 21,500 GWh in 2002, with a resulting 860 GWh for parking. Although these figures are not exclusively for parking lot lights, and do not include parking structures that are integrated into other buildings, they give an idea of the significant potential that exists for savings.

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illumination. DOE allows its test results to be distributed in the public interest for noncommercial, educational purposes only.

[11] LED Application Series: Outdoor Area Lighting. USDOE Building Technologies Program. PNNL-SA-60645.June 2008. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/outdoor_area_lighting.pdf

[12] Compound annual growth rate calculated from Navigant Consulting, Inc. (2008). "Solid State Lighting Research and Development. Multi-Year Program Plan. FY'09-FY'14."

[13] Navigant Consulting, Inc. (2002). "US Lighting Market Characterization, Volume I".

[14] Itron Inc., et al (2006). "California Energy Efficiency Potential Study".

Methodology

Host site information

The facility selected for this demonstration is a private open parking lot at a Raley's Supermarket. The site was identified through contacts at PG&E's energy efficiency program. The facility selected for this demonstration contains sixteen pole-mounted 320-watt MH fixtures. The demonstration area is approximately one half of the parking lot. Along the western property boundary are two poles with single- Type III distribution fixtures. Within the parking aisles are four poles each with two Type V distribution fixtures. The easternmost poles in the demonstration area each included one flood light directed east toward the store front. The area east of these poles was partly illuminated by the flood lights, and was not included in the illuminance performance evaluation. The north-south spacing of the poles was not consistent across the parking lot (see Figure C1). The luminaires on the southern two rows poles were replaced with LED luminaires. Although the test grid is adjacent to a row of MH luminaires, this row is spaced at almost twice the distance of the other row spacing. These luminaires should not have an impact on the test grid (see Figure C2).

Monitoring Plan

The Monitoring Plan for this demonstration called for initial, pre-installation and post-installation field visits to the parking lot. The Monitoring Plan consisted of illuminance measurements and time series power measurements. The measurements taken included: photopic illuminance, scotopic illuminance, correlated color temperature, RMS Watts, Amps, Volts, and Power Factor. Estimated energy usage from the lighting systems was also calculated based on operating schedules from the host customer and estimated load from each luminaire.

Both photopic and scotopic illuminance measurements were taken after civil twilight and when ambient light from the moon was at a minimum. Two hundred and ten (210) measurement points were laid out on a 9' x 10' grid, following as closely as possible Illuminating Engineering Society of North America (IESNA) guidance for photometric measurements of parking areas (LM-64-01). Note that photometric measurements were only taken at points within parking spaces where vehicles were not present.

The existing MH lamps were replaced with new MH lamps to provide an accurate baseline for pre-installation monitoring. Post-installation monitoring was completed with new LED luminaires. Post-installation monitoring was completed with the LED fixtures at high output and again with the LED fixtures at low output. During the course of measuring illuminance levels, ambient conditions (cloud cover and temperature) were recorded every hour. Measurement points were located in the following arrangement:

- 10 points in the north-south direction at 9' spacing
- 21 points in the east-west direction at 10' spacing

Correlated color temperature measurements were taken at no less than 3 representative locations for both MH and LED luminaires. These locations were identified by the monitoring team during photometric monitoring visits and were identical for both MH and LED luminaires.

Power measurements were recorded at 5-minute averaged intervals logged over several days, using a Dent ElitePro Datalogger. Measurements included RMS Watts, Amps, Volts, and Power Factor and were taken on the electrical circuit that includes the luminaires within the demonstration area. Monitoring equipment for power measurements was installed during MH photometric measurements by licensed professionals and was removed after power monitoring on the LED luminaires was complete.

Specific objectives of each field visit are further described below.

INITIAL FIELD VISIT (CONDUCTED JUNE 25TH, 2008)

The initial field visit was intended for project staff to become familiar with the parking facility. Specific outcomes of the initial field visit include: identify existing luminaire configuration, existing control mechanisms used for lights, and to establish the location and area of the retrofit.

PRE-INSTALLATION FIELD VISIT (CONDUCTED JULY 28TH, 2008)

The pre-installation field visit was intended to document the existing condition of the lighting system. During the visit, information was collected on illuminance, correlated color temperature, and power draw (RMS Watts, Amps, Volts, and Power Factor). Measurements were taken consistent with Appendix B: Data Collection Form. All light measurements were taken after dusk.

POST-INSTALLATION FIELD VISIT (CONDUCTED NOVEMBER 5TH, 2008)

The post-installation field visit was intended to document the new condition of the lighting system. During the visit, information was collected on illuminance, correlated color temperature, and power draw (RMS Watts, Amps, Volts, and Power Factor). Measurements were taken at the same locations where they were taken for the pre-installation visit and consistent with Attachment 1: Data Collection Form. The post-installation field visit occurred after the LED lamps had at least 100 burn hours (performed at the manufacturer's facility before on-site installation). All light measurements were taken after dusk.

ILLUMINANCE METER

Solar Light SnP Meter

CORRELATED COLOR TEMPERATURE METER

Konica Minolta Chroma Meter

POWER METER

Dent ElitePro Datalogger

Project Results and Discussion

Electrical Demand and Energy Savings

Data on the power characteristics of the base case MH luminaires and the LED luminaires were recorded over several nights for one lighting circuit serving six parking lot fixtures and one flood light using a DENT ElitePro Datalogger. The baseline measurements were taken for 8 days and the LED luminaire measurements were taken for 19 days. Because the meter was installed within the host customer's electrical room, the monitoring team relied upon the host customer's staff to install and remove the meter. The number of days metered for each luminaire is a product of when the data meter could be installed and removed.

Subtracting the measured power draw from the flood light from recorded power data, the base case MH luminaire consumed an average of 346 watts per luminaire over the monitored period. The host customer's reported schedule of operation is to run the lights for 12 hours per night, which roughly corresponds with the monitored hours of operation. As a result the estimated annual energy consumption for the luminaire, assuming 4,380 hours of operation annually, is 1,518 kWh.

Each LED luminaire was equipped with a motion sensor, which covered an estimated area of up to 47 feet in diameter[15]. The motion sensors were set to operate on high power when motion is detected, and to reduce to low power after approximately 5 minutes of no motion detection. Again subtracting the flood light power draw, the power consumption for the LED luminaires was an average of 149 watts on high power and 52 watts on low power. Over the time for which luminaires were operating, the high power mode was utilized an average of 55% of the time, resulting in an average power usage of 105 watts. This represents savings of approximately 1,056 kWh per fixture per year.

It should be noted that the percentage of time the LED luminaires operate on high power is specific to the occupancy patterns of the host customer site. Additionally, the motion sensor may be set with varying levels of time delay sensitivity, which will affect the total time LED luminaires operate in high power mode. The time delay could be set to a shorter time period in order to achieve greater energy savings. Therefore, actual savings realized from bi-level capabilities will depend on the occupancy patterns of the installation site and time delay settings on the motion sensor.

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[15] The installed motion sensor is designed to cover an area of up to 68 feet in diameter when mounted at a height of 40 feet. In this demonstration project, motion sensors were mounted at a height of approximately 29 feet, and are estimated to cover an area of up to 47 feet in diameter based on manufacturer estimates.

Calculated power and energy savings from the base case are given in the following table.

Table 1: Measured Demand and Potential Energy Savings

Luminaire Type	Power (W)	Power Factor	Power Savings (W)	Percentage of Time[16]	Estimated Annual Usage (4,380 hr, kWh)	Estimated Annual Savings (4,380 hr, kWh)
MH	346	0.88	-	100%	1,515	-
LED High Power	149	0.98	197 (57%)	55%	359	-
LED Low Power	52	0.94	294 (85%)	45%	102	-
LED Weighted Average	105	0.96	241 (70%)	100%	461	1,056

[16] Calculated based on weighted average of power measurements developed over a several day period of monitoring: Percentage of Time = (Weighted Average Power – Low Power) / (High Power – Low Power)

Lighting Performance

ILLUMINANCE

In order to compare illuminance levels from the MH and LED sources, both photopic and scotopic illuminance levels were measured. Though standards for area lighting levels are currently written only for photopic levels, illuminance levels under nighttime area lighting conditions typically fall within the mesopic range of visual perception, where both cones (which are active during photopic vision) and rods (which are active during scotopic vision) illuminance are important. For more information on mesopic illuminance, which is receiving increasing attention in the outdoor lighting design community, see Appendix B: Mesopic Illuminance.

Photopic and scotopic illuminance measurements were taken over a 90' x 210' area containing 4 luminaires, on a 9' x 10' grid. Project staff determined that MH flood lights installed on the easternmost poles in the demonstration area may have influenced the illuminance measurements to the east of these poles, therefore those points were not included in this analysis. The resulting area over which illuminance metrics were calculated was 90' x 170' area. The uniformity of the light provided by the luminaires was measured by three metrics: Coefficient of Variation (CV), Average-to-Minimum Uniformity ratio (AMU), and Maximum-to-Minimum Uniformity ratio (MMU).

CV, the standard deviation of the measured values divided by the mean, is a measure of the disparity between the actual values of all points and the average of those values. It is useful because it provides indication of the uniformity of all points across the test entire area. A lower CV is indicative of a more uniform distribution. Although CV is not a common uniformity metric, the IESNA's RP-6-01 (a different topic, but a more current document) explains the value of the CV metric. Furthermore, RP-20-98 refers and references papers on examining the statistics related to the distribution of illuminance rather than looking at a single spot.

AMU provides an indication of how low the minimum measured level is compared to the average of all measured values. It is calculated by dividing the average of all measured values by the single lowest level measured. Previously, this was a metric for parking lot lighting.

MMU provides indication of the largest disparity in illuminance level between any two points in the area of interest – the minimum measured level compared to the maximum measured level. Similar to AMU, it is calculated by dividing the single highest of all measured values by the single lowest level measured. This is the current metric for uniformity in a parking lot.

The average measured photopic and scotopic illuminance provided by the LED luminaires on high power was greater than that of the baseline MH luminaires. Additionally, the AMU, MMU and CV were reduced by the LED luminaires on high power versus the MH luminaires, indicating the LED luminaires provided a more uniform lighting distribution than the MH luminaires.

The average measured photopic and scotopic illuminance provided by the LED luminaires on low power was decreased from the baseline. However, this is for periods when no motion is detected surrounding the luminaires, and presumably the area is unoccupied. The AMU, MMU, and CV for the area between luminaires were reduced by the LED luminaires on low power, indicating more uniform lighting distribution over this area than the MH luminaires.

The IESNA recommended maintained illuminance value for parking lots when in use is 0.2 footcandles (fc) for typical conditions and 0.5 fc for enhanced security. The IESNA recognizes that in practice, retail parking lots are often lighted to a minimum of 1.0 fc. When not in use, IESNA states that "the illuminance of certain parking facilities may be turned off of reduced to conserve energy. If reduced lighting is to be used only for the purpose of property security, it is desirable that the minimum (low point) value not be less than [0.1 fc].” [17] The LED luminaire on low output exceeds the IESNA recommendations for typical in-use conditions, and when motion is detected and the LED luminaire is on high output it meets the recommendations for enhanced security.

In addition to providing recommendations about minimum illuminance, RP-20-98 recommends maximum-to-minimum uniformity ratios. These uniformity ratios are 20:1 (max/min) for basic and 15:1 (max/min) for enhanced security situations. However, as discussed in a recent journal article, both illuminance and uniformity values drastically changed between different iterations of IESNA documents[18]. The journal article further explained that little justification was provided when the metrics changed drastically. The 1993 values are provided as additional context for this demonstration. The IESNA Lighting Handbook 8th Edition provided values for parking lots which are as follows for: low-level activity a minimum illuminance of 0.2 fc; for medium activity a minimum illuminance of 0.6 fc; and for high-activity a minimum illuminance of 0.9 fc. For all these levels of activity the 8th Edition of the handbook recommends a 4:1 average-to-minimum illuminance.

Consolidated illuminance values for the LED luminaires are shown below, followed by surface plots generated to provide further qualitative understanding.

Table 2: Comparison of Measured Photopic Performance

Luminaire	Average (fc)	Minimum (fc)	Coeff. Of Variation (CV)	Avg. to Min. Uniformity (AMU)	Max to Min Uniformity (MMU)
MH	1.8	0.5	0.53	3.6 : 1	10.0 : 1
LED High Power	1.9	0.6	0.33	3.2 : 1	5.5: 1
LED Low Power	0.9	0.3	0.32	2.9 : 1	5.7: 1

Table 3: Comparison of Measured Scotopic Performance

Luminaire	Average (fc)	Minimum (fc)	Coeff. Of Variation (CV)	Avg. to Min. Uniformity (AMU)	Max to Min Uniformity (MMU)
MH	2.6	0.6	0.54	4.3:1	11.8:1
LED High Power	3.5	0.9	0.34	3.8:1	6.3:1
LED Low Power	1.5	0.6	0.33	2.7:1	5.3:1

Surface plots of the measured photopic and scotopic illuminance levels were generated using Microsoft Excel and are shown below:

[17] IESNA RP-20-98

[18] *Rational Illuminance. Gary Steffy.* Leukos Vol .2 Number 4 April 2006.

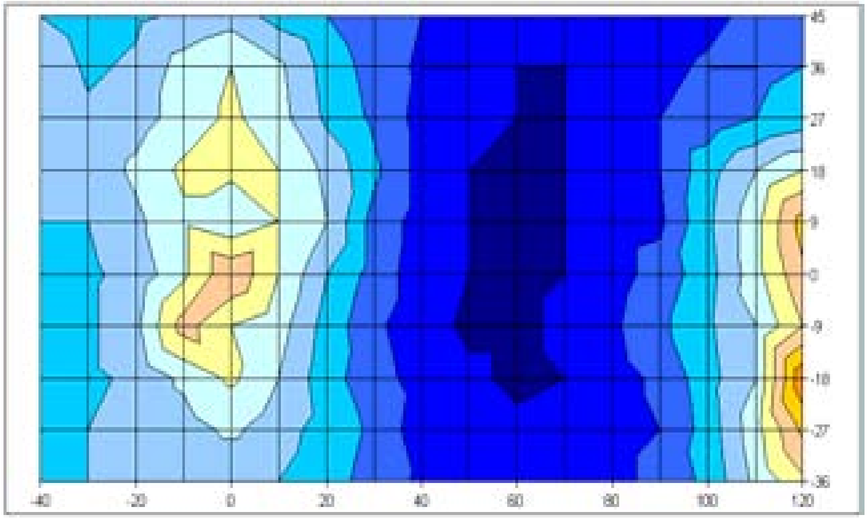


Figure 1: MH Photopic Surface Plot

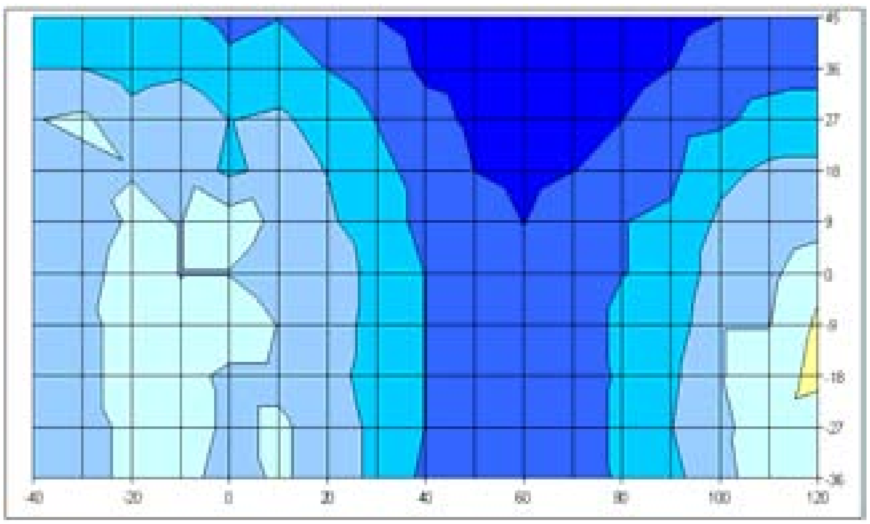


Figure 2: LED High Power Photopic Surface Plot

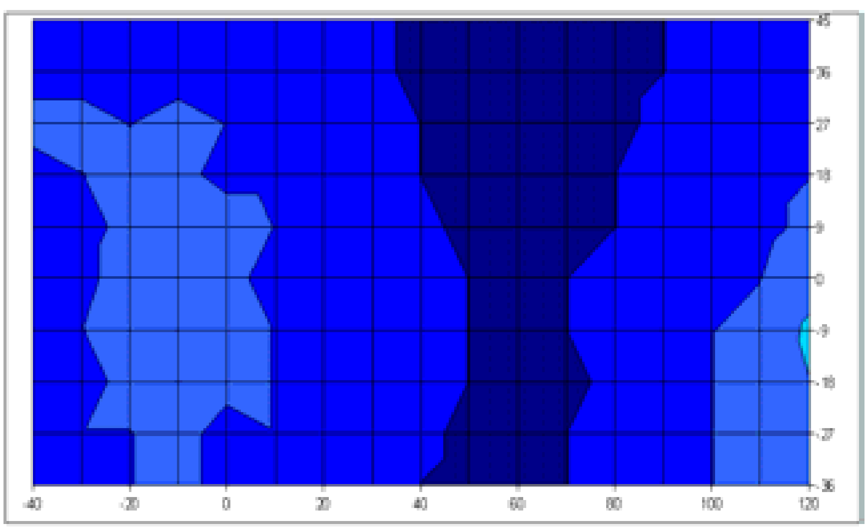
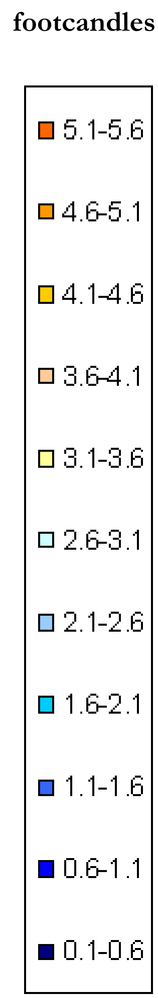


Figure 3: LED Low Power Photopic Surface Plot



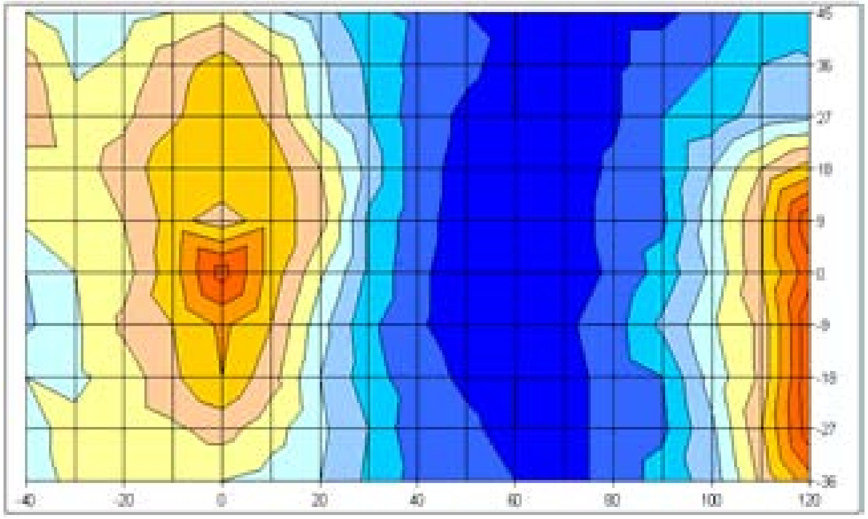


Figure 4: MH Scotopic Surface Plot

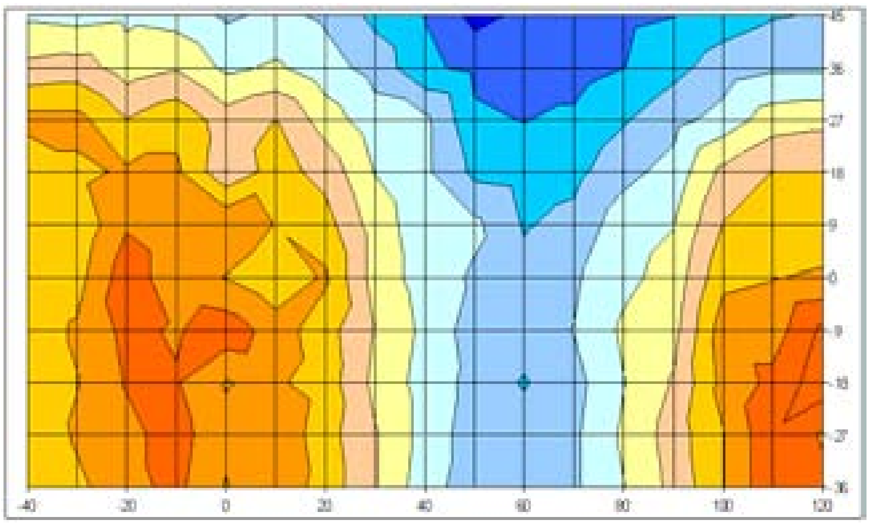


Figure 5: LED High Power Scotopic Surface Plot

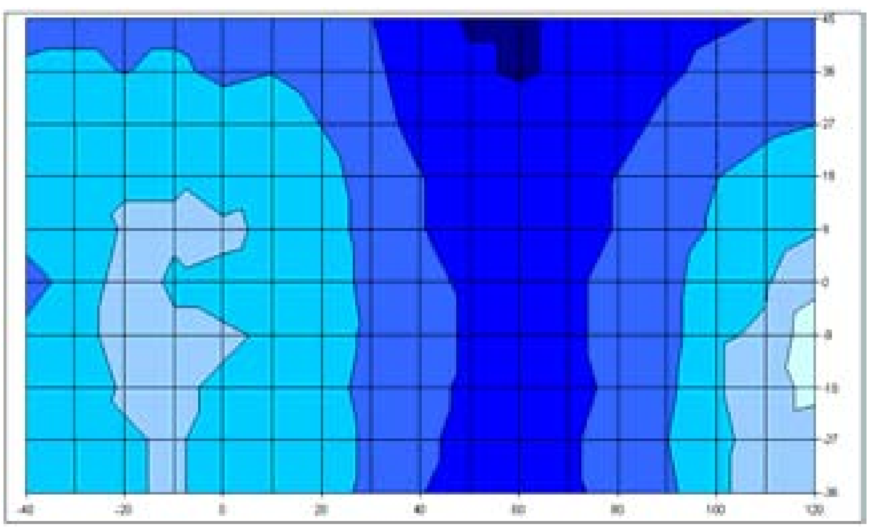
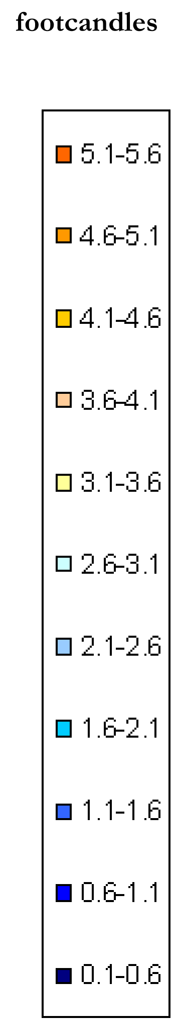


Figure 6: LED Low Power Scotopic Surface Plot



COLOR TEMPERATURE

Color temperature values were measured using a Konica Minolta Chromameter under each luminaire. The average correlated color temperature under the MH luminaires was 4621 K. The average under the LED luminaires was 5615 K. The average correlated color temperatures for each MH luminaire and LED luminaire are provided below.

Table 4: Average Correlated Color Temperature

Luminaire	Correlated Color Temperature
MH	4621
LED (High)	5615

PHOTOGRAPHIC COMPARISONS

To qualitatively analyze color rendition, various ground level photos were taken of each MH luminaires and LED luminaires under both high and low power conditions. Photos were taken with a Nikon D80 digital camera, with automatic white balance adjustment. The camera settings for the first two pictures (Figures 7 and 8) held the white balance constant for qualitative comparison of color, and were:
Flash: No
Focal Length: 18 mm
Aperture: F/8
Exposure Time: 4 sec.
White Balance: 4000K

The camera settings for the second two pictures (Figure 9 and 10), were:
Flash: No
Focal length: 18 mm
Aperture: F/8
Exposure Time: 4 sec.
White Balance: Auto

Figure 7: Overview of Demonstration Area with MH Base Case

Figure 8: Overview of Demonstration Area with LED on High Power

Figure 9: Comparison of MH Luminaires (Left) and LED Luminaires on High Power (Right)

Figure 10: Comparison of MH Luminaires (Left) and LED Luminaires on Low Power (Right)

CUSTOMER ACCEPTANCE

A survey was distributed to Raley's employees working in the West Sacramento store to obtain their feedback on the new lights (see Appendix D). A total of 17 responses were received. Of the 17 responses received, 12 employees (70%) independently noticed the new lights (i.e., apart from notification that the lights had been replaced).

The feedback from store employees was very positive; indicating that they felt the new lighting provided more light and improved the appearance of the parking lot. Overall, employees were satisfied with the new lighting, with 16 of 17 responses rated 7 or higher on a 10-point scale, with 10 being "highly satisfied". The survey responses also indicated that 16 of 17 employees would recommend that Raley's consider this type of lighting at other locations (survey response of 7 or higher on a 10- point scale). Employees also indicated that they felt safer with the new lighting.

Only two employees indicated that they had received any direct feedback from store customers about the change in parking lot lighting. In both cases, the feedback from customers was positive indicating that the parking lot looked brighter and felt safer.

Economic Performance

Energy costs, maintenance costs, and LED luminaire costs all affect economic performance of LED parking lights compared with the MH base case. Cost and savings estimates were used to evaluate economic performance of each LED luminaire versus the base case MH luminaires through simple payback and net present value (NPV) analysis[19].

To estimate energy costs for each luminaire, a 2008 PG&E E-19 off-peak rate schedule was used.[20] This rate schedule features time-of-use metering and a demand charge and is appropriate for medium general demand commercial and industrial customers. For 2008, the average off-peak rate was $0.07394/kWh. Based on the customers reported schedule the lights operate 4,380 hours per year. The annual energy cost for the MH luminaires is approximately $112/year per luminaire compared to an annual operating cost of approximately $34/year per LED luminaire.

The host customer in this demonstration contracts with a private lighting contractor for maintenance of the parking lot lighting. As a result, maintenance costs for MH were based on the reported annual maintenance costs of $200 to $215 per luminaire per year. As a conservative estimate, the low end of this range ($200) was used. This estimate includes materials, maintenance, 3-year scheduled re-lamping and periodic spot re-lamping provided by a lighting contractor. It should be noted that, according to a company employee, they were "lucky to get two years" of operation out of their previous MH lamps, despite a more typical lifetime ranging between 12-18 months.[21] This would be accounted for in the comprehensive maintenance estimates provided.

The LED luminaires were assumed to have zero regular maintenance cost over the course of their useful life, due to the robust nature of LED technology and its tendency towards rare catastrophic failure.[22] The useful life of the LED luminaires is expected to be significantly longer than that of the MH lamps.[23] Based on manufacturer's longevity and lumen depreciation claims, the predicted life for the LED luminaires is roughly 90,000 hours (approximately 21 years at 4,300 hours per year). This is significantly longer than a MH lamp, with a rated lamp of 15,000 to 20,000 hours (roughly 3 to 5 years at 4,300 hours per year). It should be noted that while a very long useful life is expected for the LED luminaires, the manufacturer provides a 5-year limited warranty with their product. It should further be noted that the actual reliability of the LED luminaire is a function of the life of all parts of the luminaire (LEDs, driver, motion sensor, housing, coating, etc.). It is also conceivable that maintenance visits may be required for the LED luminaires (such as for cleaning or other adjustments).

The calculated simple payback periods are sensitive to estimated maintenance savings, which in turn are highly dependent on the specific installation scenario. Given the present lack of field experience, true maintenance cost savings and LED luminaire reliability are difficult to assess. Readers are advised to use their own cost estimates and assumptions when possible.

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[19] NPV calculations were based on a project term of 15 years, an escalation for all costs of 3% annually, and a real discount rate of 5%. Readers are advised to use their own rates if applicable. See the Simple Payback and Net Present Value Calculations Tales in Appendix E: Economic Data and Calculations.

[20] See Appendix F: PG&E E-19 Rate Schedule.

[21] Conversation with energy manager during site visit, 6/25/2008.

[22] This is a common assumption, but is acknowledged to be speculative at this point due to the lack of actual field experience.

[23] See 'Discussion' section.

Table 5: Annual Luminaire Costs

Luminaire Type	Annual Maintenance Cost (per Luminaire)	Annual Energy Cost (per Luminaire)	Total Annual Cost (per Luminaire)
MH	$200.00[24]	$112.05	$312.05
LED	$0.00	$34.10	$34.10

Two economic scenarios were considered: a new construction scenario in which LED luminaires are installed in place of planned 320-watt MH luminaires, and a retrofit scenario in which LED luminaires are assumed to be installed in place of existing and operational 320-watt MH luminaires. The details of these scenarios are presented in the Simple Payback and Net Present Value Calculations tables of Appendix E: Economic Data and Calculations.

In the new construction scenario, the initial investment is the luminaire cost plus the cost of installation. Because the cost of installation is assumed to be the same for both luminaire types, the incremental cost for the LED luminaire is only the difference in cost relative to the MH; $925.83. The annual savings are derived from the difference in maintenance and energy costs for the two different systems ($312.05-$34.10 = $277.95). Since the assumed life of the LED luminaires is greater than the longest time period considered (15 years), end-of-life replacement costs were not included in the NPV analysis. The resulting simple payback period is 3.3 years, with a 15-year net present value of $2,661.

Table 6: Annual Luminaire Costs for New Construction

Luminaire Type	Initial Investment	Incremental Cost	Annual Savings	Simple Payback (Years)	15-Year NPV
MH	$374.17	-	-	-	-
LED	$1,300.00	$925.83	$277.95	3.0	$2,992

In the retrofit scenario, there is no assumed initial investment in the MH luminaire. As a result, the incremental cost of the LED installation is the full estimated cost of the LED luminaire, plus the cost of installation, assumed to be $150. The resulting simple payback period is 4.7 years, with a 15-year net present value of $2,287.

Table 7: Annual Luminaire Costs for Retrofit

Luminaire Type	Initial Investment	Incremental Cost	Annual Savings	Simple Payback (Years)	15-Year NPV
MH	-	-	-	-	
LED	$1,300.00	$1,300.00	$277.95	4.7	$2,287

[24] Customer reported maintenance costs ranged from $200 to $215 per luminaire per year. A maintenance cost of $200 per luminaire per year was used as a conservative approach.

Calculated simple payback periods and net present values for LED luminaires are sensitive to estimated maintenance savings, which will vary depending on a customer's maintenance practices. Because of wide differences in maintenance costs, simple payback and net present value ranges were calculated for new construction and retrofit scenarios for a range of maintenance savings estimates, assuming energy savings of $77.95 per luminaire per year. Readers are advised to use their own estimates as applicable.

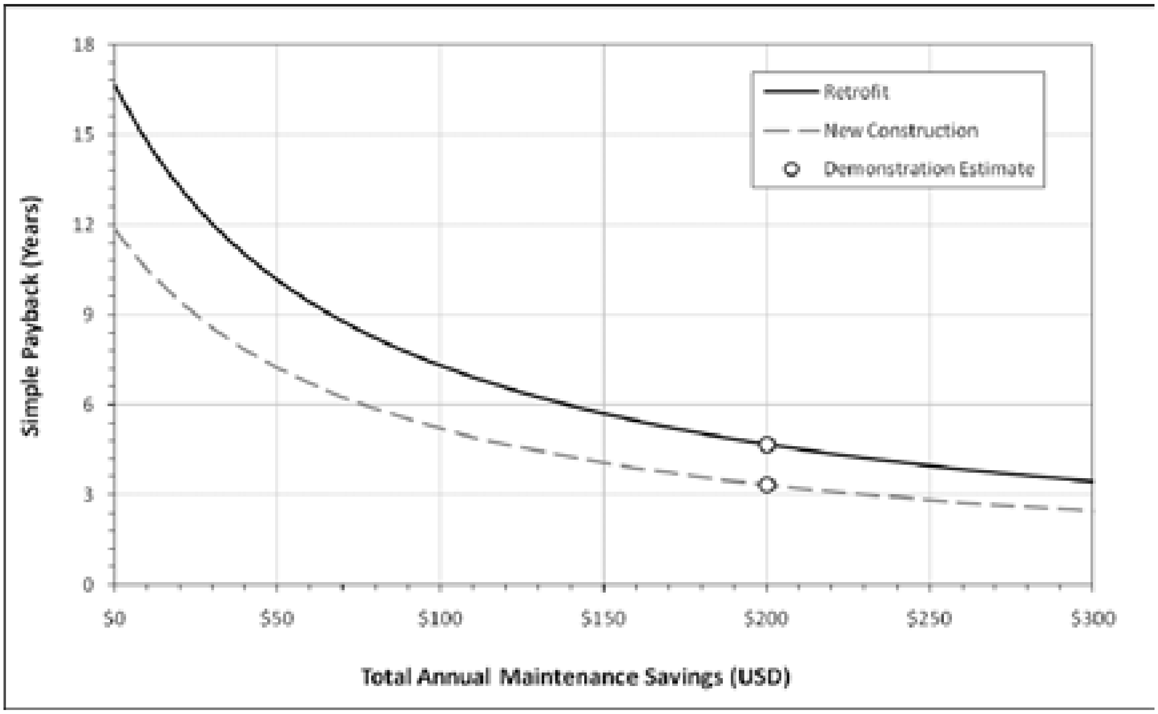

Figure 11: Estimated LED Luminaire Simple Payback for New Construction and Retrofit Scenarios[25]

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[25] This plot assumes incremental equipment costs of $925.83 and $1,300 for the new construction and retrofit scenarios, and annual energy savings of $77.95.

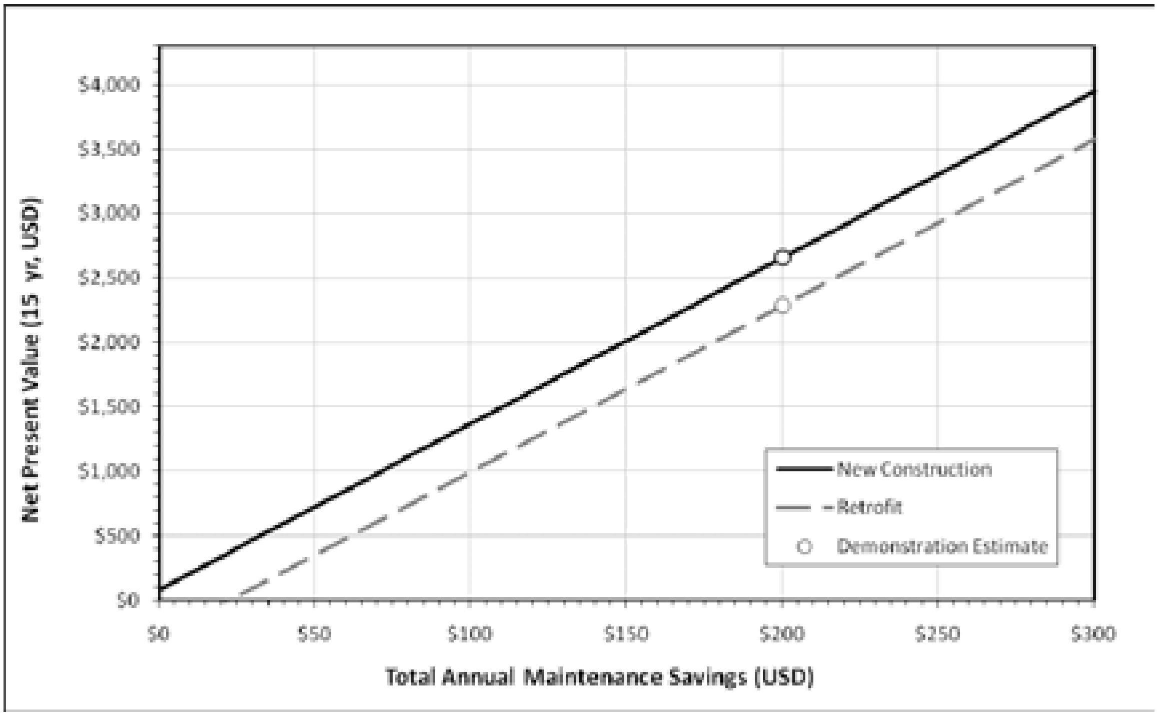

Figure 12: Estimated LED Luminaire 15-Year Net Present Value for New Construction and Retrofit Scenarios[26]

[26] This plot assumes an incremental equipment cost of $925.83 and annual energy savings of $77.95, with annual maintenance costs varying from $0 to $300. The NPV assumes a discount rate of 5.0% and an energy and labor escalation rate of 3.0%.

LED luminaire cost is the other key component of the simple payback periods. Currently, the majority of this cost is comprised by the cost of LEDs, which is declining rapidly. Indeed, Haitz's Law predicts that the light output of LEDs increases by a factor of 20 every 10 years, while the cost decreases by a factor of 10 over the same period of time. This has held approximately true beginning with red LEDs in the late 1960's and continuing with the more recent white LEDs.[27] This corresponds to a decrease in cost of 20% per year.[28] The remainder of the luminaire cost includes research and development costs, design, general overhead, manufacturing, and other material costs. The rapid decline in LED prices will likely slow as the relative cost of the LEDs versus the other material costs is lower.

The recent Emerging Technologies Program Phase III Streetlight Demonstration in Oakland provided evidence of the impressive improvement in performance at a decreased cost. Over a time period of one year, the energy savings increased by 26% (LED luminaire wattage dropped from 78 W to 58 W), and the luminaire cost decreased by 34% (bulk purchase price from $610 to $400) while maintaining equivalent lighting performance.[29] The manufacturer indicated that the majority of this savings resulted from luminaire design improvements, which offered increased optical performance for that particular application.

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[27] Steele, Robert V (2006). "The Story of a New Light Source." Nature Photonics 1, 25-26.

[28] Compound annual growth rate calculated from Navigant Consulting, Inc. (2008). "Solid State Lighting Research and Development. Multi-Year Program Plan. FY'09-FY'14."

[29] PG&E Emerging Technologies Program. (2008). LED Street Lighting, Phase III Continuation, Oakland, CA

Discussion

The installed bi-level operation LED luminaires provided sufficient illumination to be a practical replacement for the 320-watt MH luminaires. On high power, they provided increased average and minimum illumination, as well as improved uniformity over the MH fixtures. On low power, when no motion was detected by the motion sensors, they provided improved uniformity with decreased average illumination while meeting IESNA recommendations.

The power required by the LED luminaires to provide this illumination on high power was significantly less than that of the MH fixtures (57% reduction). The energy savings potential of the luminaires is further increased by dimming to a low power when no motion is detected. In this particular application, the bi-level operation of the LED luminaires was controlled by motion sensors with an approximate 5-minute time delay. This allowed them to be on low power for approximately 45% of the time. This setting was chosen to meet the desires of the host customer in this particular applications; it is likely that further energy savings would be achieved with a shorter time delay, without reducing the performance of the luminaires. On low power the LED luminaires use approximately 15% of the power required by the baseline MH luminaires, offering significant energy savings during periods when the parking lot is not occupied.

The feedback from store employees was very positive; they felt the new lighting provided more light and improved the appearance of the parking lot. Overall, employees were satisfied with the new lighting and highly recommended that Raley's consider this type of lighting at other locations. Employees also indicated that they felt safer in the parking lot at night.

It should also be noted that proper lighting design takes into account the average output of luminaires over their expected life. This is especially important when comparing different technology options, which may depreciate at different rates. Unfortunately, accepted industry standards do not currently exist to determine the lumen depreciation of LED luminaire performance over time. Since LED sources tend toward rare catastrophic failure, the commonly accepted metric for determining rated life is the amount of time the LED source takes to depreciate to 70% of its initial lumen output (known as L70). However, the most relevant currently established industry-standard testing procedure, IESNA LM-80, does not specifically provide a method for measuring depreciation at the whole luminaire level. It is instead a component (package, module or array) level test, which then must be correlated to overall performance based on the thermal and electrical properties of the luminaire. Additionally, there is not currently an accepted standard for extrapolating from the depreciation measured during LM-80 testing (6,000 hours) to depreciation over the useful life of a luminaire. The IESNA is currently working on development of a standardized method (TM-21) for extrapolation of LM-80 data, but this has not been finalized. As a result, there is no unprejudiced methodology to properly verify manufacturers' claims for lumen maintenance, so only initial outputs are considered here. Additionally, as a luminaire consists of multiple components (LEDs, driver, housing, coating, etc.), the expected useful life of the luminaire may not be the same as that of the LEDs. Instead, the lifetime should be considered to be limited by the first of all the components comprising the luminaire to fail.

Despite the electrical savings, the present high upfront cost of these bi-level operation LED luminaires may still be a barrier to widespread adoption. As is often the case, the maintenance cost savings for the LED luminaires was greater than the annual energy savings. In choosing between a MH or LED luminaire for new construction, the simple payback of the LED luminaire for this host customer would be 3.3 years, all other things remaining equal between this site and a new site. Under the retrofit scenario, where the customer has replaced a fully operational MH luminaire with a new LED luminaire, the simple payback is 4.7 years. As previously noted, these simple payback calculations are sensitive to the maintenance costs associated with specific customer circumstances.

For customers with lower annual maintenance costs, the payback period of any LED luminaire installation can be expected to be longer. However, rapid advancements in LED efficacy and a reduction in the cost of semi-conductors should continue to bring LED-luminaire costs down. Incentive programs could also help improve the cost of efficient LED outdoor lighting technology for consumers even sooner.

PG&E uses this and other Emerging Technologies assessments to support development of potential incentives for emerging energy efficient solutions. Because the performance and quality of the LED fixtures are critical to the long-term delivery of energy savings, it is important that incentive programs include quality control mechanisms. Incentive programs should include performance standards for qualifying products that include minimum criteria for warranty, efficacy, light distribution, and other important criteria.

Conclusion

LED lighting for outdoor parking lots shows great potential for energy savings. This demonstration provides evidence of increased potential savings using bi-level operation luminaires, and further evidence of the improvements in performance of LED luminaires. The costs and savings for this host customer provided favorable payback scenarios for both new construction and retrofit scenarios, due to significant maintenance and energy cost savings. Utility or government incentive programs could also help to encourage greater adoption of LED luminaires for outdoor parking lot applications by reducing the initial investment. These utility incentive programs should require minimum performance standards for qualifying products in order to ensure long-term energy savings.

Appendix A: Monitoring Data

POWER DATA

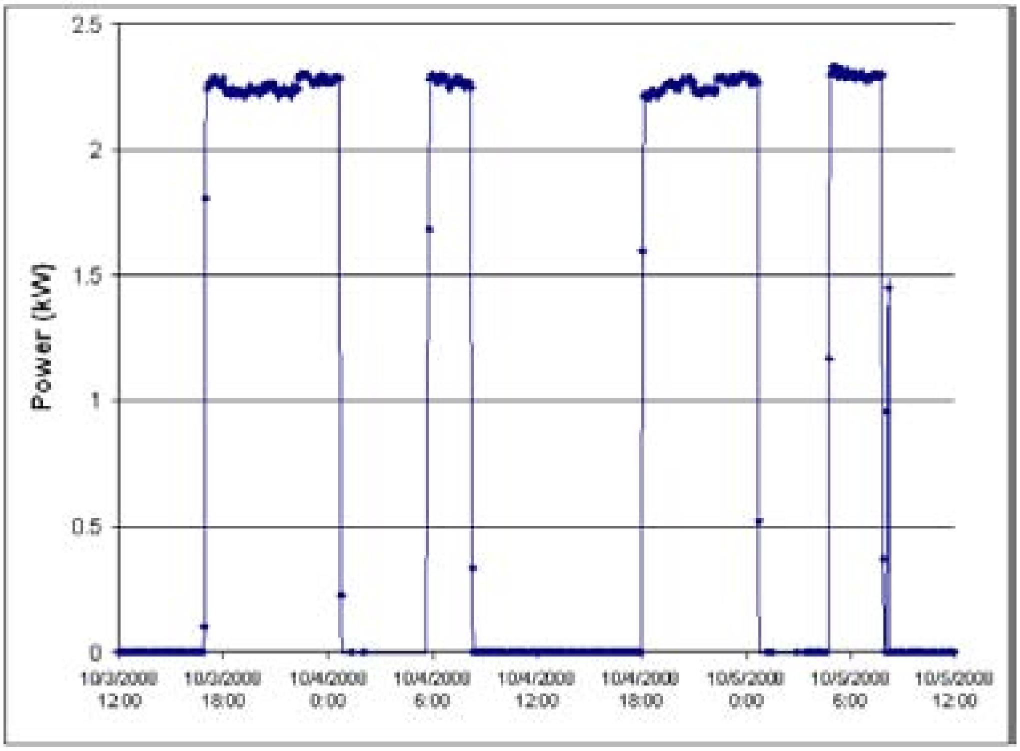

Figure A-1: Sample of MH Power Demand Data Series (six MH luminaires + one MH flood light)

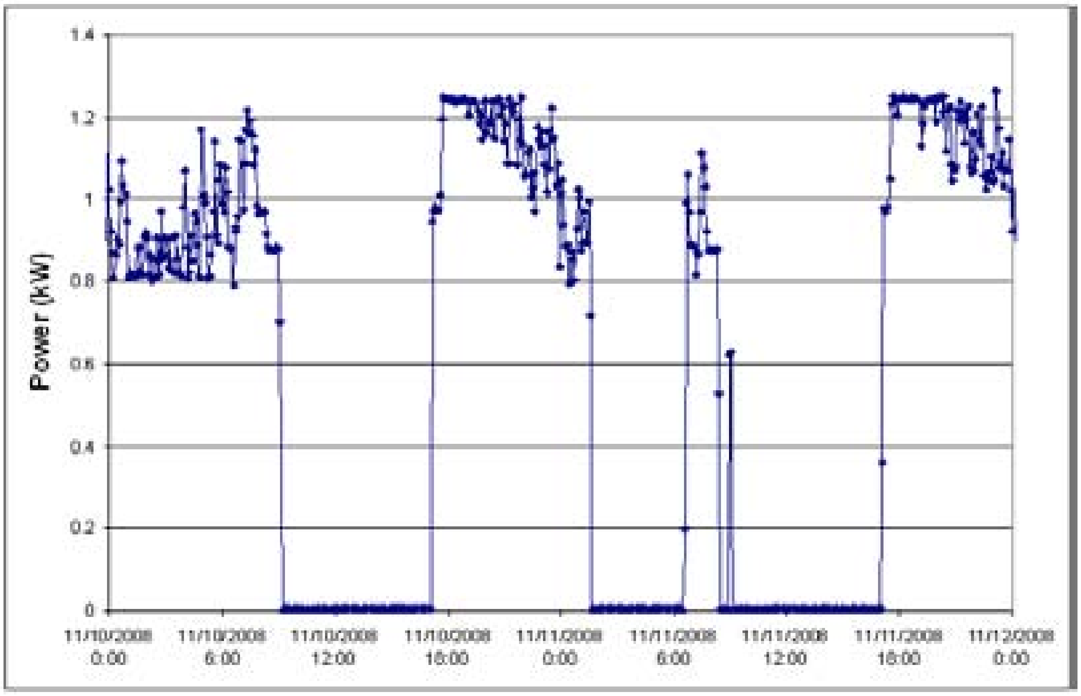

Figure A-2: Sample of LED Power Demand Data Series (six LED luminaires + one MH flood light)

(Measured with DENT ElitePro Datalogger)

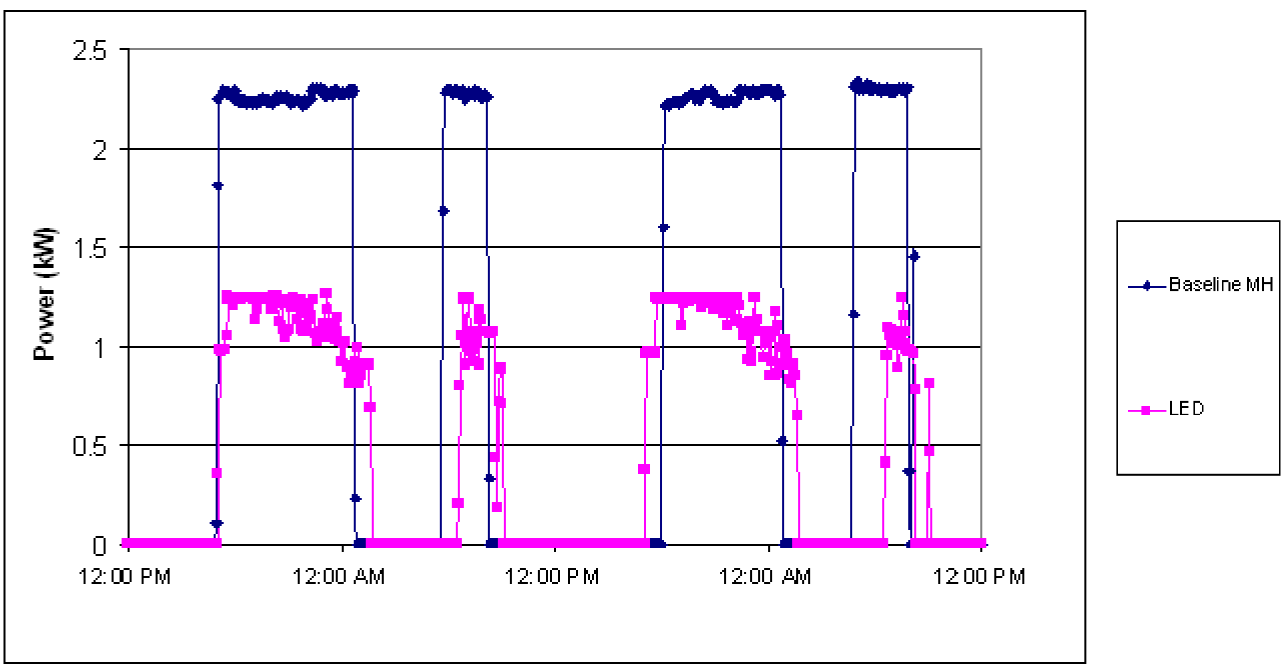

Figure A-3: Overlay of Sample MH and LED Power Demand Data Series (six luminaires + one MH flood)

(Measured with DENT ElitePro Datalogger)

MEASURED ILLUMINATION DATA

BASELINE MH DATA

Table A-1: Photopic Illumination over MH Test Area. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
45	2.1	1.8	2.0	2.2	2.4	1.9	1.6	1.2	1.1	0.8	0.7	0.7	0.7	0.7	0.9	1.3	1.1	1.2	1.2	1.0	0.6
36	2.5	2.0	2.2	2.8	3.1	2.7	1.9	1.4	1.0	0.8	0.6	0.6	0.7	0.9	1.2	1.5	1.6	1.5	1.3	1.2	0.8
27	2.6	2.2	2.4	2.8	3.2	2.8	2.0	1.5	0.9	0.7	0.6	0.6	0.7	1.1	1.3	1.6	1.8	1.8	1.8	1.8	1.4
18	2.3	2.3	2.7	3.2	3.2	3.1	2.5	1.7	0.9	0.6	0.5	0.6	0.9	1.1	1.9	2.6	3.1	2.9	2.9	2.4	2.0
9	2.1	2.1	2.5	3.0	2.7	3.1	2.6	1.4	0.9	0.6	0.5	0.6	0.9	1.0	2.0	2.9	4.3	3.8	5.2	3.1	1.8
0	1.7	2.0	2.3	3.0	4.0	3.1	2.1	1.4	0.8	0.6	0.5	0.6	0.9	1.3	1.9	2.9	4.0	4.7	3.9	5.1	2.1
-9	1.7	2.0	2.5	3.8	3.1	2.8	1.9	1.2	0.8	0.5	0.5	0.7	1.0	1.5	2.0	2.6	3.6	4.9	4.2	car	4.6
-18	2.0	2.0	2.2	2.7	3.2	2.6	1.8	1.3	0.9	0.7	0.5	0.6	0.9	1.2	1.9	2.6	5.0	4.4	4.2	4.5	2.7
-27	2.0	2.1	2.2	2.4	2.7	2.3	1.9	1.5	0.8	0.8	0.7	0.6	0.9	1.1	1.8	2.9	4.2	4.2	3.9	4.0	3.1
-36	1.9	2.1	2.2	2.2	2.2	2.1	1.8	1.4	1.0	0.9	0.8	0.6	0.9	1.3	1.7	2.7	3.5	3.6	3.2	3.0	2.0

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

Table A-2: Scotopic Illumination over MH Test Area. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
45	3.1	2.7	2.9	3.1	3.4	2.7	2.3	1.7	1.5	1.1	1.0	0.9	1.0	1.0	1.3	1.8	1.6	1.7	1.6	1.4	0.9
36	3.8	3.0	3.2	3.9	4.3	3.6	2.7	2.0	1.4	1.2	0.9	0.9	1.0	1.3	1.6	2.1	2.2	2.1	1.9	1.7	1.2
27	3.9	3.3	3.5	4.0	4.5	4.0	2.8	2.1	1.3	1.0	0.8	0.8	1.0	1.6	1.8	2.3	2.5	2.6	2.6	2.9	2.1
18	3.4	3.4	3.8	4.5	4.6	4.4	3.6	2.4	1.3	0.9	0.7	0.8	1.2	1.6	2.6	3.6	4.3	4.2	4.5	3.9	3.4
9	3.2	3.2	3.6	4.3	3.8	4.4	3.8	2.0	1.3	0.8	0.7	0.8	1.3	1.5	2.9	4.0	6.1	5.6	8.5	5.3	3.0
0	2.6	3.1	3.4	4.4	5.8	4.4	3.2	2.0	1.2	0.8	0.6	0.8	1.2	1.8	2.7	4.0	5.4	7.3	6.3	8.6	3.6
-9	2.5	3.0	3.7	4.1	4.7	4.1	2.8	1.7	1.2	0.7	0.7	1.0	1.4	2.2	3.0	3.7	6.8	7.5	6.8	car	8.4
-18	3.1	3.0	3.3	4.0	4.6	3.8	2.6	1.8	1.3	1.0	0.8	0.9	1.3	1.6	2.8	3.7	7.1	6.5	6.7	7.6	4.5
-27	3.0	3.2	3.3	3.5	3.8	3.3	2.7	2.1	1.2	1.2	0.9	0.9	1.3	1.5	2.5	4.0	5.9	6.1	6.0	6.4	5.2
-36	2.9	3.2	3.2	3.1	3.1	2.9	2.6	2.0	1.4	1.3	1.1	0.9	1.3	1.8	2.3	3.7	4.9	5.0	4.8	4.6	3.2

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

LED HIGH POWER DATA

Table A-3: Photopic Illumination over LED Test Area Under High Power. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50
45	1.7	1.7	1.7	1.7	1.5	1.6	1.4	1.1	0.9	0.6
36	2.1	2.1	1.9	2.0	1.7	1.8	1.6	1.4	1.0	0.9
27	2.6	2.7	2.3	2.5	2.1	2.2	1.9	1.6	1.3	1.0
18	2.3	2.5	2.6	2.5	2.0	2.3	2.1	1.7	1.5	1.1
9	2.4	2.3	2.7	2.6	2.9	2.5	2.2	1.8	1.5	1.3
0	2.3	2.4	2.9	2.6	2.6	2.3	2.5	1.9	1.6	1.4
-9	2.4	2.5	2.8	2.8	3.0	2.6	2.4	1.9	1.6	1.4
-18	2.4	2.5	2.8	2.8	2.5	2.5	2.3	1.9	1.6	1.3
-27	2.3	2.5	2.7	2.9	2.5	2.7	2.4	2.0	1.6	1.3
-36	2.3	2.5	2.7	2.8	2.4	2.7	2.4	2.0	1.5	1.2

	60	70	80	90	100	110	120	130	140	150	160
45	0.7	0.7	0.9	1.0	1.1	1.2	1.3	1.3	1.2	car	0.8
36	0.8	0.8	0.9	1.1	1.3	1.4	1.4	1.5	1.4	1.3	1.3
27	0.9	0.9	1.1	1.4	1.5	1.8	1.9	1.9	2.0	2.0	1.6
18	1.0	1.1	1.3	1.5	2.0	2.2	2.2	2.5	2.9	3.1	2.6
9	1.1	1.3	1.6	1.7	2.2	2.2	2.4	2.9	3.8	3.4	2.6
0	1.2	1.4	1.6	1.7	2.4	2.5	3.0	3.6	3.8	4.4	3.3
-9	1.3	1.4	1.7	1.8	2.6	2.6	3.2	3.8	4.0	9.1	10.2
-18	1.2	1.3	1.7	2.0	2.6	2.8	3.3	3.7	3.9	4.4	3.7
-27	1.3	1.4	1.7	2.1	2.5	2.9	2.7	3.4	3.8	4.4	3.7
-36	1.3	1.3	1.7	2.0	2.4	3.0	2.8	3.3	3.4	3.3	2.6

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

Table A-4: Scotopic Illumination over LED Test Area Under High Power. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
45	3.0	2.9	3.0	2.9	2.5	2.7	2.5	2.0	1.6	0.9	1.2	1.2	1.5	1.6	1.9	2.1	2.1	2.1	2.1	car	1.3
36	3.7	3.8	3.4	3.5	3.0	3.2	2.8	2.4	1.7	1.5	1.4	1.4	1.6	2.0	2.3	2.5	2.5	2.6	2.5	2.2	2.1
27	4.8	4.8	4.1	4.5	3.8	4.1	3.4	2.8	2.7	1.7	1.6	1.7	2.1	2.4	2.8	3.4	3.5	3.5	3.5	3.5	2.8
18	4.2	4.5	4.7	4.7	3.7	4.3	3.9	3.1	2.7	2.0	1.9	2.0	2.4	2.8	3.7	4.1	4.1	4.6	5.2	5.5	4.4
9	4.3	4.2	5.0	4.8	5.0	4.6	4.3	3.4	2.8	2.7	2.1	2.2	2.9	3.1	4.1	4.1	4.3	5.3	6.8	6.1	4.4
0	4.2	4.4	5.4	4.8	4.6	4.2	4.7	3.4	2.9	2.5	2.2	2.5	3.0	3.3	4.5	4.6	4.7	6.4	6.9	7.8	5.8
-9	4.3	4.7	5.2	5.0	5.4	4.9	4.3	3.5	3.0	2.3	2.3	2.6	3.2	3.5	4.9	4.9	6.7	6.6	7.1	14.9	16.4
-18	4.3	4.6	5.1	5.1	4.6	4.7	4.4	3.5	2.9	2.4	2.1	2.4	3.1	3.6	4.8	5.2	5.9	6.5	7.0	7.8	6.4
-27	4.1	4.7	5.0	5.3	4.7	5.0	4.3	3.6	2.9	2.3	2.3	2.5	3.2	3.8	4.6	5.5	5.0	6.3	6.8	7.6	6.4
-36	4.1	4.5	5.0	5.2	4.6	5.0	4.4	3.6	2.8	2.3	2.3	2.5	3.1	3.7	4.6	5.5	5.2	6.2	6.0	5.9	4.5

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

Table A-5: Photopic Illumination over LED Test Area Under Low Power. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
45	0.9	0.9	0.9	1.0	0.9	0.9	0.8	0.7	0.5	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.8	0.8	car	car
36	1.0	1.0	0.9	1.0	0.9	0.9	0.9	0.7	0.5	0.4	0.4	0.4	0.5	0.6	0.7	0.8	0.8	0.8	0.8	0.9	0.9
27	1.2	1.2	1.1	1.2	1.1	1.0	0.9	0.8	0.6	0.5	0.4	0.4	0.5	0.7	0.8	0.8	0.9	1.0	1.1	1.4	1.2
18	1.0	1.1	1.2	1.2	1.0	1.0	1.0	0.8	0.6	0.4	0.5	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.9	2.3	1.9
9	1.1	1.0	1.2	1.2	1.3	1.1	1.0	0.8	0.7	0.6	0.5	0.6	0.6	0.7	0.9	1.0	1.2	1.7	2.7	2.6	1.7
0	0.7	1.0	1.3	1.2	1.2	1.0	1.0	0.7	0.7	0.6	0.5	0.6	0.7	0.8	1.0	1.1	1.4	2.3	2.4	3.4	3.4
-9	1.0	1.1	1.2	1.2	1.2	1.1	1.0	0.8	0.7	0.6	0.5	0.6	0.7	0.8	1.1	1.2	1.7	2.5	2.5	8.4	9.6
-18	1.0	1.0	1.2	1.2	1.2	1.1	1.0	0.8	0.7	0.6	0.5	0.6	0.7	0.8	1.1	1.3	1.6	2.1	2.4	3.2	2.8
-27	1.0	1.1	1.1	1.2	1.0	1.1	1.0	0.8	0.7	0.5	0.5	0.6	0.7	0.9	1.1	1.3	1.3	1.8	2.3	3.1	2.8
-36	0.9	1.0	1.1	1.2	1.0	1.1	1.0	0.8	0.6	0.5	0.5	0.6	0.7	0.8	1.1	1.3	1.3	1.8	1.9	2.1	1.7

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

Table A-6: Scotopic Illumination over LED Test Area Under Low Power. (In fc)

	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
45	1.4	1.5	1.5	1.5	1.4	1.4	1.3	1.1	0.7	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.2	1.1	car	car
36	1.7	1.7	1.6	1.7	1.5	1.6	1.4	1.2	0.8	0.7	0.6	0.7	0.7	1.0	1.2	1.3	1.2	1.3	1.3	1.5	1.5
27	2.1	2.1	1.9	2.1	1.9	1.9	1.6	1.3	0.9	0.7	0.7	0.7	0.9	1.2	1.3	1.5	1.6	1.8	2.0	2.2	1.9
18	1.8	2.0	2.1	2.1	1.7	1.9	1.8	1.4	1.1	0.7	0.8	0.7	1.1	1.3	1.6	1.8	2.0	2.3	3.2	4.0	3.3
9	1.9	1.8	2.1	2.1	2.2	2.0	1.9	1.4	1.1	0.9	0.8	0.9	1.1	1.3	1.7	1.9	2.1	3.0	4.6	4.3	2.9
0	1.3	1.9	2.2	2.1	2.0	1.9	2.0	1.4	1.2	1.0	0.9	1.0	1.2	1.4	2.0	2.1	2.4	3.9	4.2	6.9	4.2
-9	1.8	2.0	2.2	2.1	2.1	2.1	1.9	1.5	1.3	1.0	0.9	1.0	1.2	1.4	2.1	2.1	3.0	4.2	4.3	13.2	15.1
-18	1.8	1.9	2.1	2.1	2.1	2.0	1.9	1.4	1.2	1.0	0.9	0.9	1.2	1.6	2.1	2.3	2.8	3.5	4.1	5.5	4.7
-27	1.7	2.0	2.1	2.1	2.0	2.1	1.9	1.5	1.2	0.9	0.9	1.0	1.3	1.6	2.0	2.3	2.2	3.1	3.9	5.1	4.8
-36	1.7	1.9	2.1	2.1	2.0	2.1	1.8	1.5	1.1	0.9	0.9	1.0	1.2	1.6	2.0	2.4	2.3	2.9	3.3	3.5	2.8

Shaded gray cells are not included in photometric analyses due to influence of MH flood lights

Table A-7: Photopic Illuminance Summary

Luminaire	Max (fc)	Min (fc)	Avg (fc)	Avg:Min UR	Max:Min UR	Coeff. Of Variation
MH	5.0	0.5	1.8	3.6:1	10.0:1	0.53
LED High Power	3.3	0.6	1.9	3.2:1	5.5:1	0.33
LED Low Power	1.7	0.3	0.9	2.9:1	5.7:1	0.32

Table A-8: Scotopic Illuminance Summary

Luminaire	Max (fc)	Min (fc)	Avg (fc)	Average UR	Max UR	Coeff. Of Variation
MH	7.1	0.6	2.6	4.3:1	11.8:1	0.54
LED High Power	5.9	0.9	3.5	3.8:1	6.3:1	0.34
LED Low Power	3.0	0.6	1.5	2.7:1	5.3:1	0.33

CORRELATED COLOR TEMPERATURE

Table A-9: MH Correlated Color Temperature

Luminaire	Correlated Color Temperature
1 – North	4830
1 – South	4690
2 – North	4583
2 – South	4657
3 – North	4570
3 – South	4664
4 – North	4478
4 – South	4501
Average	*4621*

Table A-10: LED Correlated Color Temperature

Luminaire	Correlated Color Temperature
1 – North	5654
1 – South	5612
2 – North	5504
2 – South	5618
3 – North	5495
3 – South	5566
4 – North	5700
4 – South	5744
Average	*5615*

Appendix B: Mesopic Illuminance

Although light levels have traditionally only been measured by photopic illuminance, human perception of light follows two distinct spectral response curves depending on the light level. The photopic spectral response curve dominates during typical daytime, and results from the "cones" in human eyes. During very low light conditions, perception follows the scotopic response curve, which results from the "rods" in the human eye. At modestly-low light levels however, such as those typical under nighttime lighting in an outdoor setting, both the photopic response curve and the scotopic response curve are important. This is known as the 'mesopic' range.

Unfortunately, the relative importance of scotopic illuminance and photopic illuminance in the mesopic range is still uncertain. However, due to the significant import of this range for nighttime outdoor lighting, one of the competing models was used to calculate 'mesopic illuminance' levels despite the controversy.

The model used to calculate mesopic illuminance in this study is the Mesopic Optimization of Visual Efficiency (MOVE) model. The MOVE model is a performance-based model developed at the Lighting Laboratory at the Helsinki University of Technology for the European Community. It was developed using the results of vision experiments which evaluated subjects' ability to complete various tasks required for night-time driving.

The MOVE model uses photopic and scotopic luminance values to calculate mesopic luminance values. The photopic and scotopic illuminance data recorded during the course of this assessment were converted into luminance, assuming that the roadway was a lambertian reflective surface with a reflectance value of 0.07[30]. The conversion formula is as follows: L (luminance) = E (illuminance) * P (reflectance of the surface)/π. The resulting photopic and scotopic luminance values were then used to calculate mesopic luminance values, which were then converted to mesopic illuminance values by the same formula.

Mesopically, the LED luminaires at high power provided a slightly increased average illumination compared with the MH base case. The LED luminaires at low power provided decreased average mesopic illumination compared with the MH base case. However, the LED luminares at both high and low power had lower average and maximum uniformity ratios, indicating the LED provided more uniform illumination.

Table B-1: Mesopic Illuminance

Luminaire	Average (fc)	Minimum (fc)	Coeff. Of Variation (CV)	Avg. to Min. Uniformity (AMU)	Max to Min Uniformity (MMU)
MH	1.8	0.5	0.52	3.5:1	9.7:1
LED High Power	1.9	0.6	0.32	3.1:1	5.2:1
LED Low Power	0.9	0.3	0.30	2.8:1	5.3:1

[30] A reflectance value of 0.07 is used for asphalt road surface with an aggregate composed of a minimum 60 percent gravel [size greater than 1 cm], asphalt road surface with 10 to 15 percent artificial brightener in aggregate mix; and asphalt road surface (regular and carpet seal) with dark aggregates (e.g., trap rock, blast furnace slag); rough texture after some months of use. Please see IESNA RP-8-00 for reflectance values for other road surface classification types.

Appendix C: Monitoring Layout

PROJECT LAYOUT

Figure C-1: Demonstration Area

Figure C-2: Test Area

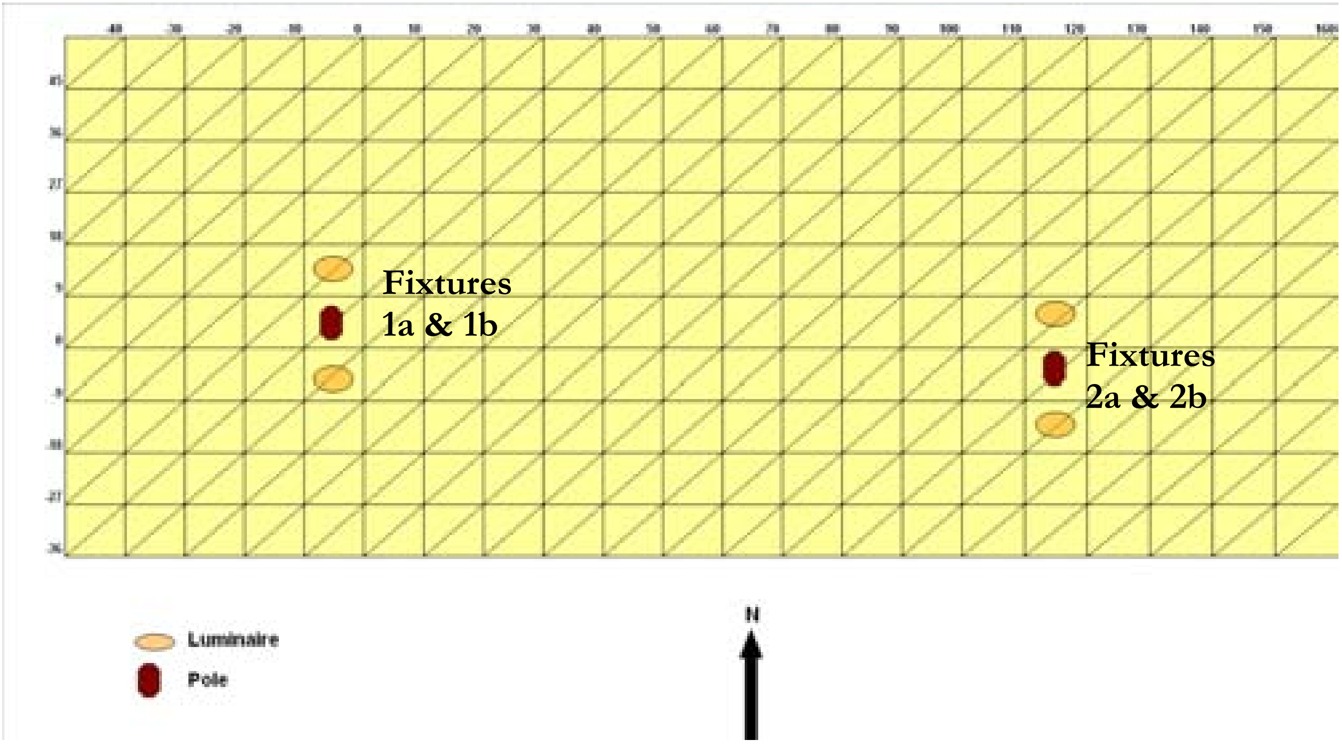

Figure C-3: Schematic of Measurement Grid

Appendix D: Customer Survey Results

The following chart summarizes the responses received from an employee survey.

Table D-1: Summary of Survey Responses

Question	Number of Responses for a Given Rating										
	1	2	3	4	5	6	7	8	9	10	Comments
1) Did you notice that new parking lot lights were installed (i.e., apart from notification that they had been replaced?) 1 indicates did not notice, 10 indicates did notice	5									12	
2) Have you overheard or otherwise received direct feedback from store customers about the change in parking lot lighting? 1 indicates Yes, 10 indicates No	2									15	2 positive comments from store customers, 0 negative or neutral comments. Comments included: "the parking lot looks brighter," and "much brighter, guest said she felt safer after dark"
3) In general, do you think the lighting improves or worsens the appearance of the parking lot? 1 indicates worsens, 10 indicates improved							3	3	4	5	Two survey responses had both 9 and 10 circled in response to this question.
4) In general, does the replacement lighting system provide more light, less light, or about the same as the original parking lot lights? 1 indicates less light, 10 indicates more light					3	1		4	2	6	One survey response had both 9 and 10 circled in response to this question.
5) In general, how satisfied are you with the new parking lot lighting? 1 indicates dissatisfied, 10 indicates satisfied					1		2	2	5	6	One survey response had both 9 and 10 circled in response to this question.
6) Would you recommend Raleys consider this type of parking lot lighting system at other store locations? 1 indicates do not recommend, 10 indicates highly recommend					1		2	2	5	6	One survey response had both 9 and 10 circled in response to this question.

Question 7 allowed for any additional comments about the new parking lot lighting system, all responses listed below:

- I like the lighting a lot better because at night I feel safer a lot more than before.
- As employees I think it is a good move more light means less theft for the store and our cars
- Its nice

Appendix E: Economic Data and Calculations

Table E-1: Annual Luminaire Energy Costs

Estimated Annual Energy Costs

Estimated Annual Savings:[1] **77.95 $ per Fixture**

320 W Metal Halide		
Demand	346.0	W
Usage[2]	1515.48	kWh
Rate[3]	0.07394	$/kWh
Annual Cost[4]	112.05	$/yr

Bi-level LED		
Demand	105.3	W
Usage[2]	461.21	kWh
Rate[3]	0.0739	$/kWh
Annual Cost[4]	34.10	$/yr

[1] 320W MH Annual Cost - LED Annual Cost

[2] Based customers reported operating schedule of 12 hours per night, 4380 hours/yr

[3] Based on PG&E E-19 Rate Structure

[4] Monthly Fixed Charge x 12

Table E-2: New Construction Economics-Simple Payback

Estimated Simple Payback for Bi-level LED Fixtures (New Construction)

Simple Payback:[1] **3.33 Years**

Details				
Incremental Cost:[2]	*925.83*	*$ per LED Luminaire*		
Annual Savings:[3]	*277.95*	*$ per Year*		
Luminaire Type:	MH	MH	MH	LED
Installation Item:	Fixture	Photocell	Lamp	Luminaire
Installation Time (Minutes):	90	-	-	90
Material Cost ($):	145.00	0.00	66.48	1,150.00
Total Additional Labor Cost ($):[4]	150.00	-	-	150.00
Item Installation Cost($):[5]	307.69	0.00	66.48	1,300.00

[1] Incremental Cost / Annual Savings
[2] Difference of total fixture installation costs
[3] Difference of energy and maintenance costs
[4] Additional Field Time x Labor Rate
[5] Material Cost + Total Additional Labor Cost

Table E-3 New Construction Economics – Net Present Value

Incremental cost ($)	$925.83
Maintenance savings ($)	$200.00
Energy savings ($)	$77.95
n (years)	15
d (discount rate)	5.0%
e (energy and labor escalation)	3.0%
d' (equivalent discount rate)	0.019417
PVF	12.90544
NPV	$2,661
Simple Payback (years)	3.33

Table E-4: Retrofit Economics – Simple Payback

Estimated Simple Payback for Bi-level LED Fixtures (Retrofit)

Simple Payback:[1] **4.68 Years**

Details

Incremental Cost:[2] *1,300.00* *$ per LED Luminaire*

Annual Savings:[3] *277.95* *$ per Year*

Luminaire Type:	MH	MH	MH	LED
Installation Item:	Fixture	Photocell	Lamp	Luminaire
Installation Time (Minutes):	-	-	-	90
Material Cost ($):	-	-	-	1,150.00
Total Additional Labor Cost ($):[4]	-	-	-	150.00
Item Installation Cost($):[5]	0.00	0.00	0.00	1,300.00

[1] Incremental Cost / Annual Savings

[2] Difference of total fixture installation costs

[3] Difference of energy and maintenance costs

[4] Additional Field Time x Labor Rate

[5] Material Cost + Total Additional Labor Cost

Table E-5: Retrofit Economics – Net Present Value

Incremental cost ($)	$1,300.00
Maintenance savings ($)	$200.00
Energy savings ($)	$77.95
n (years)	15
d (discount rate)	5.0%
e (energy and labor escalation)	3.0%
d' (equivalent discount rate)	0.019417
PVF	12.90544
NPV	$2,287
Simple Payback (years)	4.68

Appendix F: PG&E E-19 Rate Schedule

Pacific Gas and Electric Company
San Francisco, California
U 39

	Revised	*Cal. P.U.C. Sheet No.*	26940-E
Cancelling	Revised	*Cal. P.U.C. Sheet No.*	26459-E

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE

CONTENTS: This rate schedule is divided into the following sections:

1.	Applicability			(D)
2.	Territory	12.	Common-Area Accounts	(T)
3.	Rates	13.	Voluntary Service Provisions	|
4.	Metering Requirements	14.	Billing	|
5.	Definition Of Service Voltage	15.	Fixed Transition Amount	|
6.	Definition Of Time Periods	16.	CARE Discount for Nonprofit Group-Living Facilities	(T)
7.	Power Factor Adjustments			
8.	Charges For Transformer and Line Losses	17.	Electric Emergency Plan Rotating Block Outages	(T)
9.	Standard Service Facilities	18.	Standby Applicability	(T)
10.	Special Facilities	19.	Department of Water Resources Bond Charge	(T)
11.	Arrangements For Visual-Display Metering			

1. APPLICABILITY: **Initial Assignment:** A customer must take service under Schedule E-19 if: (1) the customer's load does not meet the Schedule E-20 requirements, but, (2) the customer's maximum billing demand (as defined below) has exceeded 499 kilowatts for at least three consecutive months during the most recent 12-month period (referred to as Schedule E-19). If 70 percent or more of the customer's energy use is for agricultural end-uses, the customer will be served under an agricultural schedule. Schedule E-19 is not applicable to customers for whom residential service would apply, except for single-phase and polyphase service in common areas in a multifamily complex (see Common-Area Accounts section).

Customer accounts which fail to qualify under these requirements will be evaluated for transfer to service under a different applicable rate schedule.

The provisions of Schedule S—Standby Service Special Conditions 1 through 6 shall also apply to customers whose premises are regularly supplied in part (but not in whole) by electric energy from a nonutility source of supply. These customers will pay monthly reservation charges as specified under Section 1 of Schedule S, in addition to all applicable Schedule E-19 charges. Exemptions to standby charges are outlined in the Standby Applicability Section of this rate schedule.

Voluntary E-19 Service: This schedule is available on a voluntary basis for customers with maximum billing demands less than 500 kW. Customers voluntarily taking service on this schedule are subject to all the terms and conditions below, unless otherwise specified in Section 14.

(Continued)

Advice Letter No. 3115-E-A	*Issued by*	*Date Filed*	December 27, 2007
Decision No. 07-09-004	**Brian K. Cherry**	*Effective*	January 1, 2008
	Vice President	*Resolution No.*	E-4121
107813	*Regulatory Relations*		

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

1. APPLICABILITY: (Cont'd.)

Depending upon whether or not an Installation or Processing Charge applied prior to May 1, 2006, the customer will be served under one of these rates under Schedule E-19:

Rate V: Applies to customers who were on Rate V as of May 1, 2006.

Rate W: Applies to customers who were on Rate W as of May 1, 2006.

Rate X: Applies to customers who were on Rate X as of May 1, 2006 or who qualify for the voluntary provisions of this tariff and enroll on E-19 on or after May 1, 2006.

Transfers Off of Schedule E-19: If a customer's maximum demand has failed to exceed 499 kilowatts for 12 consecutive months, PG&E will transfer that customer's account to voluntary E-19 service or to a different applicable rate schedule. After being placed on this schedule due to the 200 kW or greater provisions of this schedule, customers who fail to exceed 199 kilowatts for 12 consecutive months may elect to stay on the time-of-use provisions of this schedule or elect an applicable non-time-of-use rate schedule or alternate time-of-use rate schedule.

Assignment of New Customers: If a customer is new and PG&E believes that the customer's maximum demand will be 500 through 999 kilowatts and that the customer should not be served under a time-of-use agricultural schedule, PG&E will serve the customer's account under Schedule E-19.

Definition of Maximum Demand: Demand will be averaged over 15-minute intervals for customers whose maximum demand exceeds 499 kW. "Maximum demand" will be the highest of all the 15-minute averages for the billing month. If the customer's use of electricity is intermittent or subject to severe fluctuations, a 5-minute interval may be used. If the customer has any welding machines, the diversified resistance welder load, calculated in accordance with Section J of Rule 2, will be considered the maximum demand if it exceeds the maximum demand that results from averaging the demand over 15-minute intervals. The customer's maximum-peak-period demand will be the highest of all the 15-minute averages for the peak period during the billing month. (See Section 6 for a definition of "Peak-Period.") See Section 14 for the definition of maximum demand for customers voluntarily selecting E-19.

Solar Pilot Program: Customers who exceed 499 kW for at least three consecutive months during the most recent 12-month period and must otherwise take service on mandatory Schedule E-19 may elect service under Schedule A-6 under the terms outlined in the Solar Pilot Program section of Schedule A-6. (N)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

1. APPLICABILITY: (Cont'd.)

Standby Demand: For customers for whom Schedule S—Standby Service Special Conditions 1 through 6 apply, standby demand is the portion of a customer's maximum demand in any month caused by nonoperation of the customer's alternate source of power, and for which a demand charge is paid under the regular service schedule.

If the customer imposes standby demand in any month, then the regular service maximum demand charge will be reduced by the applicable reservation capacity charge (see Schedule S Special Condition 1).

To qualify for the above reduction in the maximum demand charge, the customer must, within 30 days of the regular meter-read date, demonstrate to the satisfaction of PG&E the amount of standby demand in any month. This may be done by submitting to PG&E a completed Electric Standby Service Log Sheet (Form 79-726).

2. TERRITORY: This rate schedule applies everywhere PG&E provides electricity service.

3. RATES: Total bundled service charges are calculated using the total rates shown below. Direct Access (DA) and Community Choice Aggregation (CCA) charges shall be calculated in accordance with the paragraph in this rate schedule titled Billing. (T)

Only customers that received the benefit of the 10 percent rate reduction prior to January 1, 2004, and who pay the Fixed Transition Amount (FTA), shall be subject to the FTA and the Rate Reduction Bond Memorandum Account (RRBMA) rates.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND METERED TIME-OF-USE SERVICE
(Continued)

3. Rates: (Cont'd.)

TOTAL RATES

Total Customer/Meter Charge Rates		Secondary Voltage		Primary Voltage		Transmission Voltage	
Customer Charge Mandatory E-19 ($ per meter per day)		$13.55236		$19.71253		$39.42505	
Customer Charge Rate V ($ per meter per day)		$4.11992		$4.11992		$4.11992	
Customer Charge Rate W ($ per meter per day)		$3.97799		$3.97799		$3.97799	
Customer Charge Rate X ($ per meter per day)		$4.11992		$4.11992		$4.11992	
Optional Meter Data Access Charge ($ per meter per day)		$0.98563		$0.98563		$0.98563	
Total Demand Rates ($ per kW)							
Maximum Peak Demand Summer		$11.59	(I)	$10.47	(I)	$8.13	
Maximum Part-Peak Demand Summer		$2.65	|	$2.40	|	$1.84	
Maximum Demand Summer		$6.89	|	$5.89	|	$3.97	(I)
Maximum Part-Peak Demand Winter		$1.00	|	$0.75	|	$0.00	
Maximum Demand Winter		$6.89	(I)	$5.89	(I)	$3.97	(I)
Total Energy Rates ($ per kWh)							
FTA	Peak Summer	$0.13289	(I)	$0.13251		$0.09787	(R)
	Part-Peak Summer	$0.09088	(R)	$0.08904	(R)	$0.07829	|
	Off-Peak Summer	$0.07372	|	$0.07029	|	$0.06660	|
	Part-Peak Winter	$0.08087	|	$0.07644	|	$0.07120	|
	Off-Peak Winter	$0.07117	(R)	$0.06689	(R)	$0.06312	(R)
Non-FTA	Peak Summer	$0.13458	(I)	$0.13420		$0.09956	(R)
	Part-Peak Summer	$0.09257	(R)	$0.09073	(R)	$0.07998	|
	Off-Peak Summer	$0.07541	|	$0.07198	|	$0.06829	|
	Part-Peak Winter	$0.08256	|	$0.07813	|	$0.07289	|
	Off-Peak Winter	$0.07286	(R)	$0.06858	(R)	$0.06481	(R)
Average Rate Limiter ($/kWh in summer months)		$0.20969	(I)	$0.20969	(I)	–	
Power Factor Adjustment Rate ($/kWh/%)		$0.00005		$0.00005		$0.00005	

Total bundled service charges shown on customers' bills are unbundled according to the component rates shown below.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND METERED TIME-OF-USE SERVICE
(Continued)

3. Rates: (Cont'd.)

UNBUNDLING OF TOTAL RATES

Customer/Meter Charge Rates: Customer and meter charge rates provided in the Total Rates section above are assigned entirely to the unbundled distribution component.

Demand Rates by Components ($ per kW)	Secondary Voltage		Primary Voltage		Transmission Voltage	
Generation:						
Maximum Peak Demand Summer	$8.12		$7.81		$8.13	
Maximum Part-Peak Demand Summer	$1.73		$1.68		$1.84	
Maximum Demand Summer	$0.00		$0.00		$0.00	
Maximum Part-Peak Demand Winter	$0.00		$0.00		$0.00	
Maximum Demand Winter	$0.00		$0.00		$0.00	
Distribution:**						
Maximum Peak Demand Summer	$3.47	(I)	$2.66	(I)	$0.00	
Maximum Part-Peak Demand Summer	$0.92	|	$0.72	|	$0.00	
Maximum Demand Summer	$4.14	|	$3.14	|	$1.22	(I)
Maximum Part-Peak Demand Winter	$1.00	|	$0.75	|	$0.00	
Maximum Demand Winter	$4.14	|	$3.14	|	$1.22	(I)
Transmission Maximum Demand*	$2.97	(I)	$2.97	(I)	$2.97	(I)
Reliability Services Maximum Demand*	($0.22)		($0.22)		($0.22)	
Energy Charges by Components ($ per kWh)						
Generation:						
Peak Summer	$0.10151		$0.10404		$0.07857	
Part-Peak Summer	$0.06639		$0.06608		$0.05899	
Off-Peak Summer	$0.05153		$0.04918		$0.04730	
Part-Peak Winter	$0.05706		$0.05406		$0.05190	
Off-Peak Winter	$0.04866		$0.04555		$0.04382	
Distribution**:						
Peak Summer	$0.01148	(I)	$0.00920	(I)	$0.00000	
Part-Peak Summer	$0.00459	|	$0.00369	|	$0.00000	
Off-Peak Summer	$0.00229	|	$0.00184	|	$0.00000	
Part-Peak Winter	$0.00391	|	$0.00311	|	$0.00000	
Off-Peak Winter	$0.00261	(I)	$0.00207	(I)	$0.00000	
Transmission Rate Adjustments* (all usage)	($0.00030)	(R)	($0.00030)	(R)	($0.00030)	(R)
Public Purpose Programs (all usage)	$0.01022		$0.00959		$0.00962	
Nuclear Decommissioning (all usage)	$0.00027		$0.00027		$0.00027	
Competition Transition Charge (all usage)	$0.00345		$0.00345		$0.00345	
Energy Cost Recovery Amount (all usage)	$0.00318		$0.00318		$0.00318	
DWR Bond (all usage)	$0.00477		$0.00477		$0.00477	
Fixed Transition Amount (all usage, when applicable)	$0.00000		$0.00000		$0.00000	
Rate Reduction Bond Memorandum Account** (all usage, when applicable)	($0.00169)		($0.00169)		($0.00169)	

* Transmission, Transmission Rate Adjustments, and Reliability Service charges are combined for presentation on customer bills.

** Distribution and applicable RRBMA charges are combined for presentation on customer bills.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

3. RATES: (Cont'd.)

a. TYPES OF CHARGES: The customer's monthly charge for service under Schedule E-19 is the sum of a customer charge, demand charges, and energy charges: (T)

- The **customer charge** is a flat monthly fee.
- This schedule has three **demand charges**, a maximum-peak-period-demand charge, a maximum part-peak-period and a maximum-demand charge. The maximum-peak-period-demand charge per kilowatt applies to the maximum demand during the month's peak hours, the maximum part-peak-period demand charge per kilowatt applies to the maximum demand during the month's part-peak hours, and the maximum demand charge per kilowatt applies to the maximum demand at any time during the month. The bill will include all of these demand charges. (Time periods are defined in Section 6.)
- The **energy charge** is the sum of the energy charges from the peak, partial-peak, and off-peak periods. The customer pays for energy by the kilowatt-hour (kWh), and rates are differentiated according to time of day and time of year.
- The meters required for this schedule may become obsolete as a result of electric industry restructuring or other action by the California Public Utilities Commission. Therefore, any and all risks of paying the required charges and not receiving commensurate benefit are entirely that of the customer.
- The monthly charges may be increased or decreased based upon the power factor. (See Section 7.)
- As shown on the rate chart, which set of customer, demand, and energy charges is paid depends on the level of the customers maximum demand and the voltage at which service is taken. Service voltages are defined in Section 5 below.

(D)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

3. RATES: (Cont'd.)

b. AVERAGE RATE LIMITER (applies to bundled service only): If the customer takes service on Schedule E-19 in either the secondary or primary voltage class, bills will be controlled by a "rate limiter" during the summer months. The bill will be reduced if necessary so that the average rate paid for all demand and energy charges during a summer month does not exceed the average rate limiter shown on this Schedule. This provision will not apply if the customer has elected to receive separate billing for back-up and maintenance service under Special Condition 8 of Schedule S. (T)

Reductions in revenue resulting from application of the average rate limiter will be reflected as reduced distribution amounts for billing purposes.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

4. METERING REQUIRE-MENTS: PG&E will install a time-of-use meter that is appropriate for this schedule that measures and registers the amount of electricity a customer uses.

(D)

Customers with a maximum demand of 200 kW or greater for three consecutive months must have an interval data meter that can be read remotely by PG&E. A Meter Data Management Agent (MDMA) may also read the customer's meter on behalf of the customer's Energy Service Provider (ESP) if a customer is receiving Direct Access Service. (T) (T)

For bundled service customers with a maximum demand of 200 kW or greater for three consecutive months, PG&E will provide and install the interval data meter at no additional cost to the customer. After the interval meter is installed, the customer must take service on a time-of-use schedule. The installation of an interval data meter for customers taking service under the provisions of Direct Access is the responsibility of the customer's Energy Service Provider, or their Agent, and must be installed in accordance with Electric Rule 22. (T) | | (T)

If the customer does not currently qualify for an interval data meter, the customer must pay PG&E for the cost of purchasing and installing an interval meter, together with applicable Income Tax Component of Contribution (ITCC) charges and the cost to operate and maintain the interval meter, and must sign an Interval Meter Installation Service Agreement (Form 79-984). (T)

Customers who also request any meter data management services must also sign an Interval Meter Data Management Service Agreement (Form 79-985) and must have an appropriate interval data meter. (L) | (L)

5. DEFINITION OF SERVICE VOLTAGE: The following defines the three voltage classes of Schedule E-19 rates. Standard Service Voltages are listed in Rule 2, Section B.1.

a. Secondary: This is the voltage class if the service voltage is less than 2,400 volts or if the definitions of "primary" and "transmission" do not apply to the service.

b. Primary: This is the voltage class if the customer is served from a "single customer substation" or without transformation from PG&E's serving distribution system at one of the standard primary voltages specified in PG&E's Electric Rule 2, Section B.1.

c. Transmission: This is the voltage class if the customer is served without transformation from PG&E's serving transmission system at one of the standard transmission voltages specified in PG&E's Rule 2, Section B.1.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

6. DEFINITION OF TIME PERIODS:

Times of the year and times of the day are defined as follows:

SUMMER	Period A (Service from May 1 through October 31):	
Peak:	12:00 noon to 6:00 p.m.	Monday through Friday (except holidays)
Partial-peak:	8:30 a.m. to 12:00 noon AND 6:00 p.m. to 9:30 p.m.	Monday through Friday (except holidays)
Off-peak:	9:30 p.m. to 8:30 a.m. All day	Monday through Friday Saturday, Sunday, and holidays
WINTER	Period B (service from November 1 through April 30):	
Partial-Peak:	8:30 a.m. to 9:30 p.m.	Monday through Friday (except holidays)
Off-Peak:	9:30 p.m. to 8:30 a.m. All day	Monday through Friday (except holidays) Saturday, Sunday, and holidays

HOLIDAYS: "Holidays" for the purposes of this rate schedule are New Year's Day, President's Day, Memorial Day, Independence Day, Labor Day, Veterans Day, Thanksgiving Day, and Christmas Day. The dates will be those on which the holidays are legally observed.

DAYLIGHT SAVING TIME ADJUSTMENT: The time periods shown above will begin and end one hour later for the period between the second Sunday in March and the first Sunday in April, and for the period between the last Sunday in October and the first Sunday in November.

CHANGE FROM SUMMER TO WINTER OR WINTER TO SUMMER: When a billing month includes both summer and winter days, PG&E will calculate demand charges as follows. It will consider the applicable maximum demands for the summer and winter portions of the billing month separately, calculate a demand charge for each, and then apply the two according to the number of billing days each represents.

7. POWER FACTOR ADJUSTMENTS:

Bills will be adjusted based on the power factor for all customers except those selecting voluntary E-19 service. The power factor is computed from the ratio of lagging reactive kilovolt-ampere-hours to the kilowatt-hours consumed in the month. Power factors are rounded to the nearest whole percent.

The rates in this rate schedule are based on a power factor of 85 percent. If the average power factor is greater than 85 percent, the total monthly bill will be reduced by the product of the power factor rate and the kilowatt-hour usage for each percentage point above 85 percent. If the average power factor is below 85 percent, the total monthly bill will be increased by the product of the power factor rate and the kilowatt-hour usage for each percentage point below 85 percent.

(D)

Power factor adjustments will be assigned to distribution for billing purposes.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

8. CHARGES FOR TRANSFORMER AND LINE LOSSES: The demand and energy meter readings used in determining the charges will be adjusted to correct for transformation and line losses in accordance with Section B.4 of Rule 2.

9. STANDARD SERVICE FACILITIES: If PG&E must install any new or additional facilities to provide the customer with service under this schedule the customer may have to pay some of the cost. Any advance necessary and any monthly charge for the facilities will be specified in a line extension agreement. See Rules 2, 15, and 16 for details. This section does not apply to customers voluntarily taking service under Schedule E-19.

Facilities installed to serve the customer may be removed when service is discontinued. The customer will then have to repay PG&E for all or some of its investment in the facilities. Terms and conditions for repayment will be set forth in the line extension agreement.

10. SPECIAL FACILITIES: PG&E will normally install only those standard facilities it deems necessary to provide service under this schedule. If the customer requests any additional facilities, those facilities will be treated as "special facilities" in accordance with Section I of Rule 2.

11. ARRANGEMENTS FOR VISUAL-DISPLAY METERING: If the customer wishes to have visual-display metering equipment in addition to the regular metering equipment, and the customer would like PG&E to install that equipment, the customer must submit a written request to PG&E. PG&E will provide and install the equipment within 180 days of receiving the request. The visual-display metering equipment will be installed near the present metering equipment. The customer will be responsible for providing the required space and associated wiring.

PG&E will continue to use the regular metering equipment for billing purposes.

(D)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

12. COMMON-AREA ACCOUNTS: Common-area accounts that are separately metered by PG&E and which took electric service from PG&E on or prior to January 16, 2003, have a one-time opportunity to return to a residential rate schedule from April 1, 2004 to May 31, 2004, by notifying PG&E in writing. (T)

In the event that the CPUC substantially amends any or all of PG&E's commercial or residential rate schedules, the Executive Council of Homeowners (ECHO) can direct PG&E to begin an optional second right-of-return period lasting 105 days. However, if this occurs prior to the April 1, 2004 to May 31, 2004, time period, the ECHO directed right of return period will be the only window for returning to a residential schedule.

Newly constructed common-areas that are separately metered by PG&E and which first took electric service from PG&E after January 16, 2003, have a one-time opportunity to transfer to a residential rate schedule during a two-month window that begins 14 months after taking service on a commercial rate schedule. This must be done by notifying PG&E in writing. These common-area accounts have an additional opportunity to return to a residential schedule in the event that ECHO directs PG&E to begin a second right-of-return period.

Only those common-area accounts taking service on Schedule E-8 prior to moving to this tariff may return to Schedule E-8.

Common-area accounts are those accounts that provide electric service to Common Use Areas as defined in Rule 1.

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

13. VOLUNTARY SERVICE PROVISIONS: Customers voluntarily taking service on Schedule E-19 (see Applicability Section) shall be governed by all the terms and conditions shown in Sections 1 through 12, unless different terms and conditions are shown below. (T)

a. DEFINITION OF MAXIMUM DEMAND: Demand will be averaged over 15-minute intervals except, in special cases. "Maximum demand" will be the highest of all 15-minute averages for the billing month.

SPECIAL CASES: (1) If the customer's use of energy is intermittent or subject to severe fluctuations, a 5-minute interval may be used; and (2) If the customer uses welders, the demand charge will be subject to the minimum demand charges for those welders' ratings, as explained in Section J of Rule 2.

b. REDUCED CUSTOMER CHARGE: The reduced customer charge will be assessed only if the customer is taking service under this schedule on a voluntary basis or if the customer's maximum billing demand has not exceeded 499 kW for 12 or more consecutive months.

c. SERVICE CONTRACTS: This rate schedule will remain in effect for at least twelve consecutive months before another schedule change is made, unless the customer's maximum demand has exceeded 499 kW for three consecutive months.

14. BILLING: A customer's bill is calculated based on the option applicable to the customer. (T)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

14. BILLING: (Cont'd.)

Bundled Service Customers receive supply and delivery services solely from PG&E. The customer's bill is based on the Total Rates and Conditions set forth in this schedule. (T)

Transitional Bundled Service Customers take transitional bundled service as prescribed in Rules 22.1 and 23.1, or take bundled service prior to the end of the six (6) month advance notice period required to elect bundled portfolio service as prescribed in Rules 22.1 and 23.1. These customers shall pay charges for transmission, transmission rate adjustments, reliability services, distribution, nuclear decommissioning, public purpose programs, the FTA (where applicable), the RRBMA (where applicable), the applicable Cost Responsibility Surcharge (CRS) pursuant to Schedule DA CRS or Schedule CCA CRS, and short-term commodity prices as set forth in Schedule TBCC.

Direct Access (DA) and Community Choice Aggregation (CCA) Customers purchase energy from their non-utility provider and continue receiving delivery services from PG&E. Bills are equal to the sum of charges for transmission, transmission rate adjustments, reliability services, distribution, public purpose programs, nuclear decommissioning, the FTA (where applicable), the RRBMA (where applicable), the franchise fee surcharge, and the applicable CRS. The CRS is equal to the sum of the individual charges set forth below. Exemptions to the CRS are set forth in Schedules DA CRS and CCA CRS.

Energy Cost Recovery Amount Charge (per kWh)
Power Charge Indifference Adjustment (per kWh)
DWR Bond Charge (per kWh)
Ongoing CTC Charge (per kWh)

Total CRS (per kWh)

15. FIXED TRANSITION AMOUNT:

Eligible small commercial customers that received the benefit of the 10 percent rate reduction prior to January 1, 2004, are obligated to pay a Fixed Transition Amount (FTA), also referred to as a Trust Transfer Amount (TTA), as described in Schedule E-RRB and defined in Preliminary Statement Part AS. In addition, these customers will receive the benefit of the rate reduction bond memorandum account rate. (T)

16. CARE DISCOUNT FOR NONPROFIT GROUP-LIVING AND SPECIAL EMPLOYEE HOUSING FACILITIES:

Facilities which meet the eligibility criteria in Rule 19.2 or 19.3 are eligible for a California Alternate Rates for Energy discount under Schedule E-CARE. CARE customers are exempt from paying the DWR Bond Charge rate component. For CARE customers, no portion of the rates shall be used to pay the DWR bond charge. Generation is calculated residually based on the total rate less the sum of the following: Transmission, Transmission Rate Adjustments, Reliability Services, Distribution, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges (CTC), Energy Cost Recovery Amount, FTA and the Rate Reduction Bond Memorandum Account Rate. (T)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

17. ELECTRIC EMERGENCY PLAN ROTATING BLOCK OUTAGES

As set forth in CPUC Decision 01-04-006, all transmission level customers except essential use customers, Optional Binding Mandatory Curtailment (OBMC) plan participants, net suppliers to the electrical grid, or others exempt by the Commission, are to be included in rotating outages in the event of an emergency. A transmission level customer who refuses or fails to drop load shall be added to the next rotating outage group so that the customer does not escape curtailment. If the transmission level customer fails to cooperate and drop load at PG&E's request, automatic equipment controlled by PG&E will be installed at the customer's expense per Electric Rule 2. A transmission level customer who refuses to drop load before installation of the equipment shall be subject to a penalty of $6/kWh for all load requested to be curtailed that is not curtailed. The $6/kWh penalty shall not apply if the customer's generation suffers a verified, forced outage and during times of scheduled maintenance. The scheduled maintenance must be approved by both the ISO and PG&E, but approval may not be unreasonably withheld. (T)

(Continued)

COMMERCIAL/INDUSTRIAL/GENERAL
SCHEDULE E-19—MEDIUM GENERAL DEMAND-METERED TIME-OF-USE SERVICE
(Continued)

18. STANDBY APPLICABILITY: SOLAR GENERATION FACILITIES EXEMPTION: Customers who utilize solar generating facilities which are less than or equal to one megawatt to serve load and who do not sell power or make more than incidental export of power into PG&E's power grid and who have not elected service under Schedule NEM, will be exempt from paying the otherwise applicable standby reservation charges. (T)

DISTRIBUTED ENERGY RESOURCES EXEMPTION: Any customer under a time-of-use (TOU) rate schedule using electric generation technology that meets the criteria as defined in Electric Rule 1 for Distributed Energy Resources is exempt from the otherwise applicable standby reservation charges. Customers qualifying for this exemption shall be subject to the following requirements. Customers qualifying for an exemption from standby charges under Public Utilities (PU) Code Sections 353.1 and 353.3, as described above, must take service on a TOU schedule in order to receive this exemption until a real-time pricing program, as described in PU Code 353.3, is made available. Once available, customers qualifying for the standby charge exemption must participate in the real-time program referred to above. Qualification for and receipt of this distributed energy resources exemption does not exempt the customer from metering charges applicable to TOU and real-time pricing, or exempt the customer from reasonable interconnection charges, non-bypassable charges as required in Preliminary Statement BB - *Competition Transition Charge Responsibility for All Customers and CTC Procurement*, or obligations determined by the Commission to result from participation in the purchase of power through the California Department of Water Resources, as provided in PU Code Section 353.7.

19. DWR BOND CHARGE: The Department of Water Resources (DWR) Bond Charge was imposed by California Public Utilities Commission Decision 02-10-063, as modified by Decision 02-12-082, and is property of DWR for all purposes under California law. The Bond Charge applies to all retail sales, excluding CARE and Medical Baseline sales. The DWR Bond Charge (where applicable) is included in customers' total billed amounts. (T)