Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Final Report #0718

LED Cove, Accent, and Spot Lighting II: Hospitality Sector

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Project Manager: Daryl DeJean
Pacific Gas and Electric Company

Prepared By: Marc A. Theobald, LEED AP
Senior Energy Analyst
EMCOR Energy Services
505 Sansome Street, Suite 1600
San Francisco, CA 94111
(415) 434-2600

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Preface

EMCOR Energy Services, under contract to Pacific Gas & Electric Company (PG&E), conducted this study of an Emerging Technology Project at a project host site, the Hilton Hotel, located in San Francisco, California. The purpose of this project is to assist PG&E with the evaluation of the application of LED lighting systems to cove, accent, and spot lighting in the hospitality sector, as discussed herein.

This report is the result of an emerging technology demonstration project performed as a part of the Customer Energy Efficiency (CEE) Program administered by PG&E. This program is part of PG&E's commitment to meeting new demand growth through energy efficiency by providing technical assistance directly to electric service customers.

EMCOR Energy Services of San Francisco, California, prepared this document for PG&E under the CEE Program. The PG&E Emerging Technologies Program Lead is Lee Cooper. The PG&E Project Manager for this project is Daryl DeJean.

The EMCOR Energy Services Project Manager for this study is Marc Theobald. The authors of this report are Marc Theobald, Kit Legg, E.I.T., and Jack Howells. The report was reviewed for technical quality by Merlin Luedtke, P.E.; it was edited by Meghan Williams.

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1 Executive Summary

This report summarizes the installation and assessment of light emitting diode (LED) luminaires at a full service hospitality center in Northern California, the Hilton Hotel. Relying primarily on field-testing, the project team conducted photometric and power measurements, as well as employee satisfaction surveys and economic payback calculations.[1] This application assessment study was designed to verify the brightness and quality of light currently achievable with LED lighting systems in order to aid the acceleration of their mainstream adoption in the hospitality end-use.

The baseline equipment for this study consisted of various types of lighting systems common to the hospitality setting; a chandelier was lit by clear incandescent 40W A-lamps, a hallway by compact fluorescent lamps located in recessed downlights, an entryway alcove area illuminated by linear T8 fluorescent fixtures, and a seating area by recessed MR16 halogen spot lamps.

These lighting systems were replaced as follows:

- **Accent hallway lighting, chandeliers**

Thirty-seven 40 W screw-based incandescent lamps were replaced by thirty-seven LED screw-based, lamp-like luminaires in a single decorative crystal chandelier.

- **Ambient hallway lighting, recessed cans**

Twenty screw-in LED PAR30 form factor lamps replaced an equivalent number of 30 W compact fluorescent screw-in “twist” lamps located in recessed can down light fixtures located in the Plaza B hallway area.

- **Ambient light, spa elevator entrance cove**

A total of ten three-foot and four-foot linear T8 fluorescent lamps powered by solid-state ballasts were replaced with nine 4' LED light bars and associated drivers in the spa area cove lighting application.

- **Task light, spa waiting area**

Nine 20 W halogen MR16 lamps were replaced by nine LED luminaires with a pin-based, MR16 form factor in a wall-wash application in the waiting area.

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[1] Throughout this report, “employee” or “project host” refers to the host site (who may otherwise be referred to as a customer of PG&E’s electricity service). “Customer” will refer only to customers of the host facility.

Results of the photometric field measurements are tabulated in Table 1.1.[2] Since illuminance is a measure of incident light, this report deems illuminance most capable of expressing customer and hotelier perception, ultimately the most important criteria in hospitality facility lighting. Measurements of luminance (luminous intensity) were performed for the chandelier test, where the primary function of this accent lighting system is to provide visual interest in the chandelier and the surroundings as opposed to general illumination.

This study details the performance of LED luminaires as compared to previously reported trends on the application of LED lighting systems. Illuminance measurements in the hallway, cove, and spa seating area were noted as reduced in the LED application relative to the base case. A review of the calculated maximum to minimum levels suggests reduced uniformity with the replacement LED luminaires.

Field measurements reveal higher levels of reflected light from the surface of the chandelier crystals under the test case (LED) lighting as compared to the base case incandescent lighting system. This result indicates the aptness of LED lighting for applications which are primarily decorative. Importantly, and again consistent with other application assessment studies, customer feedback related to all four of the field tests was generally positive despite variances in illumination levels. The chandelier replacement LED system was noted to be, “a big contrast to the other chandeliers in the area.” This was due in large part to the color variance of the test case in contrast to the original chandelier lighting systems.

Table 1.1 Summary of Photometric Measurements

Lighting System	Average Luminance (cd/m2)	Average Illuminance (fc)
Chandelier Accent Lighting		
40W A	81.9	N/A
Replacement LED	233.2	N/A
Δ (%)	173%	N/A
Hallway Down Lighting		
Compact Fluorescent	N/A	3.1
PAR30 LED	N/A	0.9
Δ (%)	N/A	(71%)
Spa Cove Fluorescent Lighting		
T8 Linear Fluorescent	N/A	3.3
LED Light Bar	N/A	1.3
Δ (%)	N/A	(61%)
Spa Seating Area Lighting		
MR-16 Halogen	N/A	4.2
MR-16 LED	N/A	2.6
Δ (%)	N/A	(38%)

2 Illuminance levels are not presented for the chandelier accent lighting test because the effect of the chandelier on general illuminance could not be properly isolated from the general lighting (See Section 4.3.4 for more details.)

Electric demand was measured before and after project installation. This information was used to quantify energy savings resulting from installation of the LED lighting systems. Measurements indicate that the projects overall reduced the electric demand of the baseline lighting systems by approximately 78 percent. The combined annual lighting energy savings for these projects were 15,183 kWh.

The overall performance of each LED luminaire was examined in terms of level of illuminance provided and electric demand reduced, since formal efficacy values were not available.

Table 1.2 Summary of Overall Luminaire Performance

Lighting System	Total Baseline Power (kW)	Total LED Power (kW)	Energy Savings (kWh/yr)	Demand Reduction (%)	Δ Illuminance Reduction (%)*
Chandelier Accent LED medium base	1.369	0.074	11,344	95%	
Hallway Down lighting PAR30 LED luminaire	0.480	0.260	1,927	46%	(71%)
Spa Cove 4' LED light bars	0.232	0.092	1,143	60%	(61%)
Spa Seating MR16 LED luminaire	0.189	0.072	769	62%	(38%)
		Project Energy Savings	15,183		

* Illuminance measurements not available for the chandelier. (See Section 4.3 for more details.)

It is also important to note that the baseline T8 fluorescent lighting system replaced in this study was relatively modern and efficient. The savings estimates for this application are, thus, conservative relative to older, less efficient baseline equipment. The compact fluorescent source used in the downlight application is more efficacious than halogen sources that are typically used for this type of application; therefore the savings estimates for the downlight application are conservative relative to standard practice. The spa seating area and chandelier systems use incandescent sources, which are deemed typical lighting systems for accent lighting applications in the hospitality sector.

The costs of electricity and electrical demand were calculated based on the time-based occurrence of project savings using PG&E's E-20S rate, typical for large hotels and hospitality centers. Additionally, LED luminaires have been shown to demonstrate a much greater effective useful life than fluorescent or other conventional lighting systems.[3] This results in fewer equipment replacements and lower maintenance costs.

[3] Building Technologies Program, February 2007.

More than two cycles of fluorescent lamp replacements will be avoided during the expected life of the cove LED system, and more than 16 incandescent lamp replacements will be avoided during the expected life of the chandelier and spa seating area lighting systems. Annual energy use and maintenance cost savings are detailed in the table below.

Table 1.3 Annual Energy and Maintenance Cost Savings

Lighting system	Annual Cost Savings			Project Cost	Payback (yrs)	
	Energy ($/yr)	Maint. ($/yr)	Total ($/yr)		Energy Savings Only	Energy and Maintenance Savings
Chandelier Accent LED medium base	$1,169.57	$869.87	$2,039.44	$855.07	0.7	0.4
Hallway Down lighting PAR30 LED luminaire	$198.67	$290.00	$488.67	$1,502.20	7.6	3.1
Spa Cove 4' LED light bars	$117.84	$220.20	$338.04	$1,538.19	13.1	4.6
Spa Seating MR16 LED luminaire	$79.28	$363.51	$442.79	$360.99	4.6	0.8
Total	$1,565.36	$1,743.58	$3,308.94	$4,256.45	2.7	1.3

Given current market conditions, the combined installation cost of the four applications is estimated to be approximately $4,256, resulting in a simple payback period of 2.7 years based on energy savings alone. When maintenance savings are included, the overall simple payback period is calculated to be 1.3 years. Based on effective useful life that ranges between 5.7 and 7.6 years for the various measures, the life-cycle cost is positive overall.

LED lighting is a rapidly advancing technology. It is anticipated that on-going improvements in materials science, thermal efficiencies, optical design, as well as installation methods will lead to continuing price reductions and greater energy savings. Economies of scale are also predicted to drive manufacturing prices down. In the near term, utility incentive programs can reduce initial cost and potentially accelerate market adoption of this promising energy efficient technology.

2 Project Background

2.1 LED Technology Overview

A light emitting diode (LED) is a semiconductor diode that emits light from a p-n junction when electric current is applied in the forward direction. A p-n junction is formed when a P-type semi-conductor (a semi-conductor doped to increase the amount of positive free charge carriers) is connected to a N-type semiconductor (a semi-conductor doped to increase the amount negative free charge carriers). The wavelength of the emitted light, and therefore its perceived color, depends on the semi-conductor materials of which the p-n junction consists. Additionally, the lens of the LED can be coated in order to further effect the wavelength of light emitted.

Although developed in the 1960s, application of LEDs has been limited due to color and performance restrictions imposed by the availability of primary usable elements within the diode: initially red only. LEDs developed in the 1980s incorporated new materials that allowed flexibility in the design of LED output color, and engendered commercial applications such as exit signs, indicators, and traffic signals.

The 1990s saw the advent of blue and consequently of white LED sources (white light from LEDs is produced by combining red, green, and blue LED sources or by coating a blue LED with yellow phosphor). This was a breakthrough that offered a much broader range of applications than previously available. Due to continuous research and development in the technologies of semiconductors and optics, LEDs are now well known as efficient lighting technologies. Recent advances in the technology’s materials science have also extended LED expected life, brightness, and efficacy. Today’s technology affords a burgeoning array of LED applications, many of which are gaining acceptance in the marketplace.

2.2 Application Assessment Studies

Few application assessment studies have been completed on the application of LED cove or spot-lighting to the lodging and hospitality end-use. This section discusses some relevant studies into LED lighting that are completed or pending.

In 2007, “Marketable Technologies for the Hospitality Industry” (PG&E Application Assessment Report # 0609) was published through the Energy Technologies Coordinating Council (ETCC), a utility consortium operating in coordination with the California Energy Commission to promote developments in energy efficient technologies. The study investigated (25) emerging technologies with potential to save substantial energy and electric demand in the lodging industry. Proposed LED applications were limited to integral nightlights for occupancy sensor-controlled restroom vanity fixtures.

Fluorescent sources were noted as the primary options for efficient guestroom lighting. The report underscores the relative lack of consideration of LED sources to the hospitality sector as recently as 2007.

A companion report to the current effort, PG&E Application Assessment Report #0717, "LED Cove, Accent, and Spot Lighting: Hospitality Sector") was recently published (2008) and made available through the ETCC. The study conducted field tests on a variety of applications and concluded that LED sources may meet customer requirements for certain hospitality applications, particularly for accent lighting.

PG&E Application Assessment Report #0617, "LED Case, Cove, and Display Lighting: Macy's (Northern California)" (2008) showcased LED technology in retail display applications, some of which bear resemblance to the requirements of accent and cove lighting found in common areas of facilities associated with the hospitality sector. Also related to the retail sector is PG&E Application Assessment Report #0728, "LED MR16 Lighting Demonstration: West Sacramento, CA" (2008) which studied the replacement of low voltage MR16 lamps with LED equivalent sources in retail display lighting application.

Also, Southern California Edison is currently conducting studies of a variety of LED applications through the ETCC. One such study deals with under-cabinet lighting (publication ET 07.03). It aims to evaluate energy savings and demand reductions of LEDs over incandescent and fluorescent lighting systems. A related study (ET 07.14) is being conducted to investigate the use of LED systems as replacements for MR16 low voltage lighting apparatus. A third study (ET 07.12) is underway to investigate the use of screw-based modular LED assemblies as direct replacements for directional incandescent display lighting, such as afforded by R and PAR lamps.

The Department of Energy Solid-State Lighting Gateway Demonstration is sponsoring ongoing studies in residential under-cabinet lighting. These studies hope to confirm the efficacy of available LED lighting solutions and improved customer acceptance as compared to fluorescent lighting. Importantly, these studies will seek to gain data on the directional quality of LED light:

> *Light sources that emit in 360 degrees lose a fair portion of their lumen output (typically 30% or higher) in directional lighting applications due to the required reflection (and partial absorption) of those lumens emitted outside of the desired pattern. LEDs can deliver light more efficiently to the desired surface.*[4]

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[4] Department of Energy, May 2008

2.3 Current Technical and Market Status

Lighting of indoor public spaces spans a number of lighting categories, primarily cove, spot, and accent lighting; which have traditionally been provided by a combination of fluorescent and incandescent sources. Halogen lamps with narrow beam focus are often used to provide the intensity and accuracy of light necessary for detailed or noticeable displays.

The application of LED lighting technology to indoor public spaces, such as the common areas within a hotel, offers many opportunities for technology penetration in this field. IESNA summarizes the basic goal for hospitality facility lighting:

> *In designing lighting for hospitality facilities, which include hotels, motels, and food service facilities, the first task is to identify those items that the staff and users want or need to see. Both groups must be able to see and comprehend their environment in order to move about and work within it. In addition, they should enjoy the environment. In facilities such as hotels and restaurants, the psychological effects of lighting are particularly important. By creating an attractive, comfortable, and functional environment, the lighting design becomes a marketing tool. Moreover, the lighting design must be integrated with the overall architectural design.*[5]

The emphasis on comfort implies an interest in creating mood rather than emphasis on product sales, as is the case in retail lighting applications.

Although current design and manufacturing processes can employ LED lighting in a number of traditional form factors and applications, LED lighting offers promise for innovative design in the ability to deliver light in non-traditional forms; the multitude of possible color and intensity choices, and the inherent directionality and uniformity of light provided by solid-state lighting.

LED sources are more efficacious than incandescent and halogen sources, but less so than fluorescent sources. While current LED products generally emit less total flux (light output) than the baseline products they are replacing, uniformity and directionality have been shown in various application assessment studies to demonstrate acceptable replacement strategies. LED light sources are continuing to improve in terms of efficacy, and luminaire design is also undergoing refinement in terms of thermal and optical efficiency; luminaire efficacies have reached approximately 50 lumens per watt (lm/W).

Multipurpose LED light bars (a linear track of individual LEDs that mimic the form and distribution of fluorescent fixtures) and medium-base and pin-based MR16 luminaires are available from several manufacturers, including LED Power and IMS. Manufacturers

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[5] IESNA, 2000. p. 13-1.

typically claim a minimum of 50,000 hours of unit life, along with additional benefits of safe low-voltage operation, non-product-deteriorating light (LED sources do not emit ultraviolet light), cool operation ideal for heat sensitive products, and mercury free, environmentally friendly technology.

Light bar design is currently integrated, forcing the replacement of the entire light bar with the failure of LED components. Self-ballasted assemblies, for example an LED luminaire manufactured to replace an incandescent lamp, integrate heat sink and driver; these are replaced completely upon failure. LED MR16 and other lamp-like assemblies offer the advantage that they can be obtained for use with standard MR 16 or medium base sockets to meet the requirements of existing conditions but must be tested to ensure compatibility with the existing track transformer.

3 Project Objectives

The objective of the PG&E Emerging Technologies Program is to accelerate the market penetration of energy-efficient technologies, applications, and tools that have not yet been widely adopted in California. Application assessment studies, such as this serve to measure, verify, analyze, and document the potential energy savings and electric demand reduction of specific technologies and applications in different market segments.

This study focused on the following objectives in order to gauge the current feasibility and performance of the application of LED light sources to the hospitality environment, categorized as the Lodging-Hotel and Lodging-Motel end-uses in the Database for Energy Efficient Resources (DEER):

- The quantitative comparison of the luminance, illuminance, and correlated color temperature measured in the field application of four different LED luminaires and baseline lighting systems to four different lighting scenarios.
- The quantification of potential energy savings which incorporated data logs from isolated lighting circuits and in-house product bench testing to determine the level of demand and energy savings currently achievable by LED luminaires.
- The solicitation of feedback from the hotel staff and management regarding the project implementation and outcome.

4 Experimental Design and Procedure

4.1 Project Background and Timeline

Prior to this study, PG&E had identified LED sources as an emerging technology application for hospitality display lighting, developed test objectives and conditions, and identified a project host, Hilton Hotel San Francisco, to participate in the study.

This application assessment study was designed to measure the performance of four lighting systems in four different lighting applications. PG&E worked with the project host to identify the following lighting systems and applications:

- **Incandescent lamps providing accent hallway lighting, chandeliers**

Thirty-seven 40 W screw-based incandescent lamps were replaced by thirty-seven LED screw-based, lamp-like luminaires in a single decorative crystal chandelier.

- **Compact fluorescent lamps providing ambient hallway lighting, recessed cans**

Twenty screw-in LED PAR30 form factor lamps replaced an equivalent number of 30 W compact fluorescent screw-in “twist” lamps located in recessed can downlight fixtures located in the Plaza B hallway area.

- **Linear fluorescent lighting providing ambient light in spa elevator entrance cove(s)**

A total of ten three-foot and four-foot linear T8 fluorescent lamps powered by solid-state ballasts were replaced with nine 4' LED light bars and associated drivers in the spa area cove lighting application.

- **Halogen MR16 lamps to provide task light in the spa waiting area**

Nine 20 W halogen MR16 lamps were replaced by nine LED luminaires with a pin-based, MR16 form factor in a wall-wash application in the waiting area.

Photographs of sample baseline and LED lighting systems for each test area are shown on the following pages. Photographs including superimposed photometric data from in-field photometric measurements areas are included in Appendix B.

Figure 4.1 Baseline Chandelier Lighting (40W Incandescent lamps)

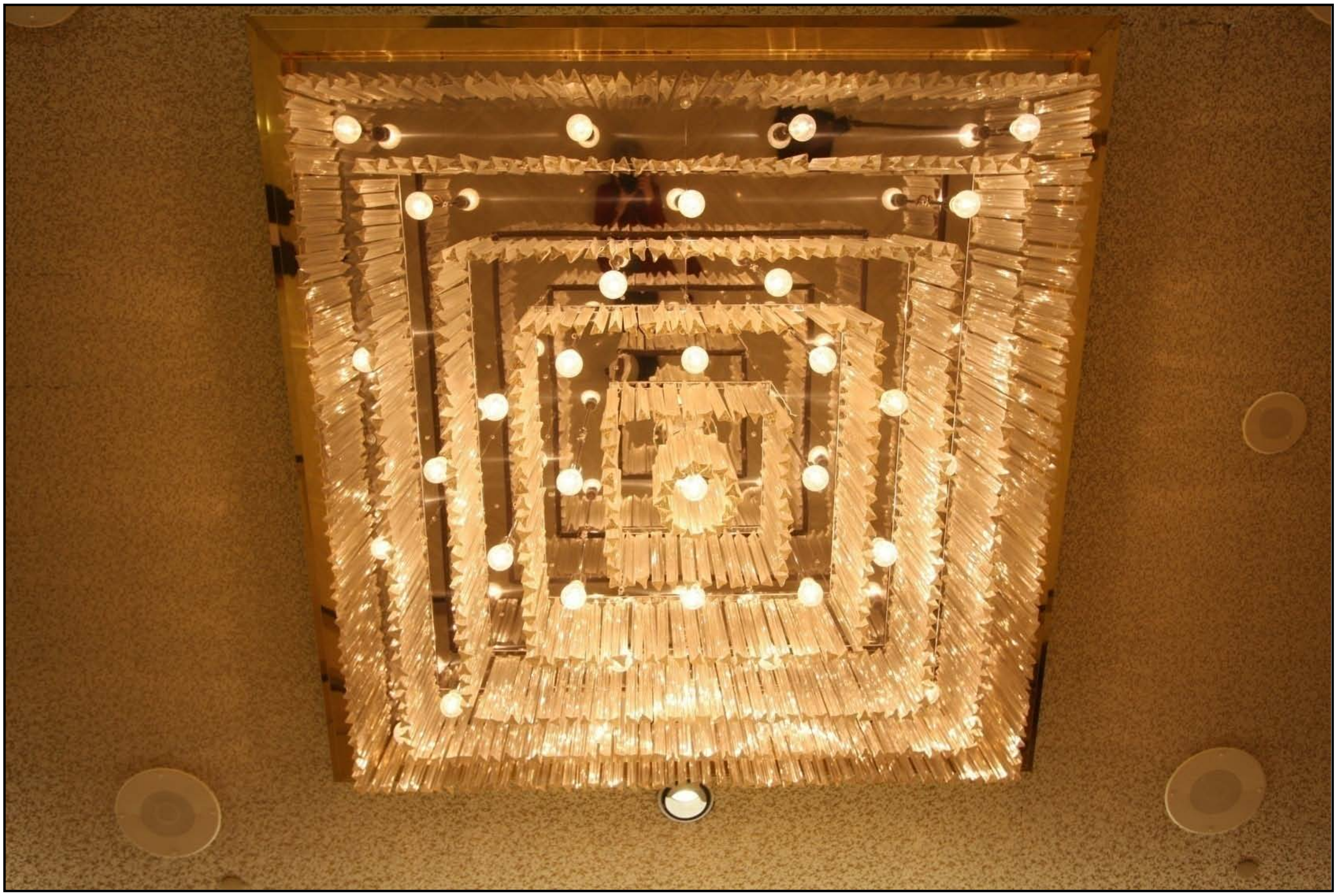

Figure 4.2 LED Chandelier Lighting (LED screw-based luminaires)

Figure 4.3 Baseline Hallway Downlights (30W Compact Fluorescent Lamps)

Figure 4.4 LED Hallway Downlights (LED screw-based luminaires)

Figure 4.5 Baseline Spa Cove Lighting (T8 Fluorescent lamps)

Figure 4.6 LED Spa Cove Lighting (LED Lightbar luminaires)

Figure 4.7 Baseline Spa Seating Lighting (20W Halogen MR16 lamps)

Figure 4.8 LED Spa Seating Lighting (LED pin-based luminaires)

PG&E drafted a scope of work outlining the basic steps required for a field evaluation of this technology. The project team drafted a test protocol to be used in planning for and conducting the field-testing of the baseline and LED lighting systems.[6]

The following are key dates and milestones of the project:

October 29, 2007

Project kick-off meeting: PG&E, project host, and project evaluation team were present to identify potential test sites and discuss project parameters.

February 19, 2008

PG&E, project host, and project evaluation team were present to finalize test sites and discuss project parameters.

February 28, 2008

Baseline photographs and photometric testing performed.

March 5, 2008

Electric demand data logger installed to record baseline power measurements for baseline fluorescent lighting (cove lighting).

April 2, 2008

Electric demand logger disconnected and power measurements collected. However, one of the voltage leads had been disconnected during the recording period and measurements are suspect.

April 24, 2008

Electric demand data logger installed to record power measurements for baseline fluorescent lighting and test LED lighting (cove lighting).

May 15, 2008

Electric demand logger disconnected and power measurements collected.

November 6, 2008

Photographs and photometric testing of LED lighting systems performed.

November 11, 2008

Project host provided with Customer Feedback Survey.

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6 See Appendix A.

November 20, 2008

Customer Feedback Surveys returned.

January 6 2009

Short-term power measurements performed in the field for the spa cove lighting base and test cases using electric demand data logger.

January 8, 2009

Illuminance measurements performed for the spa cove base and test case lighting systems, as well as the MR16 halogen and MR16 replacement LED lighting systems. Spot verification of electrical demand for cove base and test case lighting systems, using RMS clamp meter.

4.2 Product Information and Installation

The LED luminaires were provided by two manufacturers. Light bars, PAR30 replacement LED assemblies, and 2 W medium-screw-base luminaires were provided by LEDPower. The medium-base LED luminaires were provided as a prototype, therefore no product specifications or information is available. The 4.7 W pin-based MR16 LED replacement luminaires were provided by IMS. Product specifications are provided in Appendix D.

All projects were installed by the project host facilities staff. Employees replaced thirty-seven 40 W screw-based incandescent lamps with thirty-seven LED screw-based, lamp-like luminaires on a one-for-one basis in a single decorative crystal chandelier. Following the photometric measurements, employees re-instated the original incandescent lighting.

When the study was conceived, most of the recessed downlight fixtures located in the Plaza B hallway were equipped with PAR 38 halogen lighting. During the course of the study, employees altered the base case lighting system and fitted the recessed fixtures with screw-based 30 W “twist” type compact fluorescent lamps. The project was adjusted so that baseline power and photometric measurements were performed using the compact fluorescent lamps as the base case. Subsequent to the testing, the Plaza B hallway underwent a remodeling and the lighting systems were renovated.

Site personnel installed the LED cove lighting as an alternate rather than as a replacement lighting system for the pre-existing fluorescents. The base case linear fluorescent lighting system consists of a typical cove configuration of continuous T8 fluorescent lamps mounted in the cove, utilizing white enamel reflectors to direct light out of the cove towards the upper portion of the elevator wall. The test case LED lightbars were set end-to-end on top of the fluorescent fixture housing cove encasement in such a way that neither system impacts the lighting distribution provided by the other. However, the LED system was pointed straight towards the ceiling rather than optimally aimed to direct more light out of the cove. The LED system was equipped with one Advance driver that was rated at a maximum of 100 W; this limited the maximum power available to the test case system and caused the LED light bars to be under driven relative to their maximum rated power. The installation included a two-way toggle switch so that one system would be engaged at a time. Both systems and the toggle switch remained in place following conclusion of the study.

In the spa area, lamps were angled downwards towards the wall which created an overlapping scalloped pattern with the main beams directed toward the mid-point of the wall. Employees replaced several recessed, amiable pin-based fixtures equipped with MR16 lamps with MR-16 form factor LED replacement luminaires. The test case lamps were installed with the intention of replicating the lighting distribution pattern that had been provided by the base case lighting system. The test case lighting remained in place at the conclusion of the study.

4.3 Photometric Field Measurements

4.3.1 General Approach

The project team devised a testing protocol for the purpose of characterizing the lighting system performance.[7] Lighting performance was measured and assessed in terms of three main attributes: luminance, illuminance, and correlated color temperature. The Lighting Design Lab provides an online glossary of lighting terms; key terms are described below as a background to the test parameters.[8]

- **Luminance:** The luminous intensity of a surface in a given direction per unit area of that surface as viewed from that direction; often incorrectly referred to as "brightness."
- **Illuminance:** The density of incident luminous flux on a surface; illuminance is the standard metric for light levels, and is measured in lux (lx) or footcandles (fc).
- **Correlated color temperature (CCT):** The absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source; measured in Kelvin.

One of the requests that preceded this study was for existing fluorescent lamps to be replaced with new fluorescent lamps and to ensure they operated prior to testing (burned in) for at least 100 hours to stabilize the baseline condition. This adjustment to the baseline condition was intended to allow the comparison of the light output of existing and replacement light sources at the same point of depreciation, in this case as new.

4.3.2 Measurement Locations

Photometric measurements were taken at repeatable locations on nearby surfaces including the following:

- The vertical surface of the wall between the elevators for the fluorescent lighting system,
- The vertical surface of the wall washed by the MR16s for the halogen lighting system,
- The vertical surface of the wall near the downlights; and
- The crystalline surface of the chandelier.

Additional detail relative to each type of photometric test is provided in the following sections. For consistency between pre- and post-installation conditions, luminance measurements were performed at the same positions and from the same viewing angles in both cases. Luminance maps are provided for review in Appendix B; photometric results in tabular form are located in Appendix C.

[7] See Appendix A for the full testing protocol.

[8] Lighting Design Lab n.d.

4.3.3 Luminance Measurements

Luminance was measured in candela per square meter (cd/m^2). The chandelier was selected for luminance measurements in order to gauge the changes in reflected light from the crystalline surfaces as a rough approximation of “sparkle”.

Luminance measurements were conducted on the surface of the chandelier crystal surfaces. The lighting task was judged to be visual interest in the fixture itself, which is best gauged by the amount of available reflected light. The pattern is an "X" shape at the four corners and in the center of the chandelier, on the crystalline surfaces.

For both the incandescent and the replacement LED lighting systems in the chandelier, luminance readings were taken directly on the chandelier crystals from the ground on the four corners and in the center.

4.3.4 Illuminance Measurements

Illuminance values for this study were recorded in footcandles (fc). Because visual perceptions of space and the need to maintain a high degree of visual interest dominate the lighting requirements for hospitality environments, vertical surfaces were selected for measurement. A visual representation of measurement locations is located in Appendix B.

For the downlighting and replacement LED lighting systems, the lighting task was to illuminate the surrounding pathway and décor. Measurements were taken on the wall of the hallway, at eye level, so as to illuminate these elements. Five positions were recorded on the wall space of the hallway within the beamspread of a single fixture. The pattern is an "X" shape with two readings on the top row (72” above the floor), one middle reading (at 51” high), and two measurements on the bottom row (30” high). Measurements were performed on the vertical surface with the illuminance meter perpendicular to the horizon. The downlights are the major contributing light source in the hallway; a lighted framed picture in the vicinity was not switched off while the measurements were performed.

In the spa cove area, illuminance measurements were performed on the vertical wall paneling located between Elevators 4 and 5. The height from floor to cove is 100", and the door panel area is 64" wide. For both the base and test case, twelve (12) measurements were performed on a 4x3 grid. Readings were taken nominally at eye level to correspond with the visual task of illuminating the elevator area while "washing" the wall paneling. Measurements were performed on the vertical surface with the illuminance meter perpendicular to the horizon. Other contributing general and accent lighting systems were switched off while the measurements were performed.

In the spa seating area, illuminance measurements were performed on the vertical wall within the spread pattern of a single fixture. Base and test case lighting measurements were taken in separate locations with similar conditions. For both the base and test case, twenty (20) measurements were performed on a 4x5 grid, taken just above the furniture to correspond with the visual task of illuminating the artwork while also creating an overlapping scalloped pattern on the wall surface. Measurements were performed on the vertical surface with the illuminance meter perpendicular to the horizon. Other contributing general and accent lighting systems were switched off while the measurements were performed.

Sample illuminance measurements were performed in the vicinity of the chandelier. The test area was also illuminated by other lighting sources so the chandelier results could not be properly isolated; therefore, the results have not been included in this study. The measured effect of replacing the chandelier light bulbs did not indicate a consistent or significant change to the overall illuminance levels.

4.3.5 Correlated Color Measurements

Correlated color measurements, measured in Kelvin (K), were recorded using the Konica Minolta CL-200 Chroma Meter in a number of locations for each test area.

4.4 Electric Demand Measurements

The project team developed an electric demand measurement protocol for the purpose of determining the electric demand and the energy use of the baseline and LED lighting systems.

An electric demand data logger was installed pre-programmed to record voltage, current, power factor, and electric demand at 15-minute intervals. The circuit associated with the cove lighting was identified in the lighting control panel as Breaker #12. This breaker included additional lighting load that could not be isolated. However, the overall usage pattern of the circuit was judged to be similar to the usage of the cove lighting, which is the primary load. This initial test data was therefore extrapolated and used to calculate an approximation of the annual use.

As previously explained, site personnel had installed the LED cove lighting as an alternate rather than as a replacement lighting system for the pre-existing fluorescents, complete with a two-way switch so that one or the other system could be engaged but not both simultaneously. Power measurements were taken at 1-minute intervals for a period of 30 minutes under both conditions to ascertain the total draw of the cove lighting system. Spot verification of electrical demand for cove base and test case lighting was conducted using a RMS clamp meter.

Since the chandelier lighting system, downlights and the halogen lighting system circuits could not be isolated, the power measurements for single lamps from each application were performed in-house using power testing equipment as indicated below.

4.5 Testing Equipment

The following monitoring equipment used in the execution of this Monitoring Plan:

- **Correlated Color Temperature Meter/Illuminance Meter**
  Konica Minolta CL-200 Chroma Meter with ±2% accuracy; last calibrated October 2007.

- **Illuminance Meter**
  Greenlee 93-172 Digital Light Meter, foot candles range (Fc): 0.01 to 5000, Incandescent Light Source: +/- 4% Other Light Sources: +/- 7%

- **Luminance Meter**
  Konica Minolta LS-100 Spot Luminance Meter with ±2% accuracy, last calibrated 10/2007

- **Electric Demand Meter**
  DENT ElitePro Data Logger with ±0.5% accuracy typical; last calibrated April 2007.

- **True RMS Clamp Meter**
  Fluke 335 Serial 90457523 with a range of 0 - 600.0 V and accuracy of 1% ± 5 counts

5 Facility Information

The host facility is the Hilton Hotel San Francisco in San Francisco. PG&E provides electrical service to the facility. Hotels in PG&E's service territory normally qualify for an E-20S time-of-use electricity rate because electric demand often exceeds 1,000 kW. The actual utility information for this site is held confidential by the owner and was not used in the development of this report.

The E-20S rate schedule is a time-of-use tariff, which means that electricity is provided at different rates depending on the time of day it is used. Based on PG&E E-20S rate schedule information, the average electricity cost during the occurrence of project savings was calculated to be $0.1031/kWh; this figure includes demand charges.[9]

[9] Refer to Appendix C-2 for rate information and time-of-use rate calculations.

6 Project Results

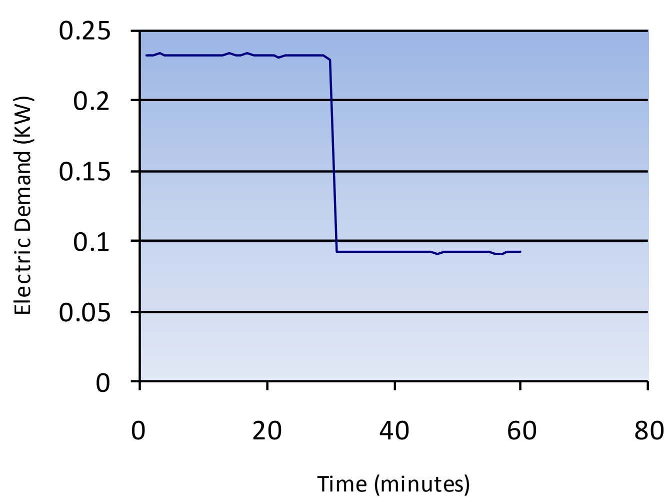
6.1 Electrical Energy and Demand Savings

Calculations of electrical energy and demand savings are based on electric demand measurements from baseline and LED luminaires.[10] Savings from the LED light bars are calculated based on electric demand logged for the base case and test case cove lighting systems. Since the circuits for the medium-base incandescent and halogen MR16 lamps could not be isolated, calculations are based on the extrapolation of in-house electric demand measurements.

6.1.1 Electric Demand Measurements

Figure 6.1 shows data from the 1-hour testing period during which the electric demand data logger was installed. For 30 minutes, the data logger was set to record the power draw associated with a powered switch leg that included 10 fluorescent fixtures, including (7) four-foot F32T8 fluorescent lamps and (3) three-foot F25T8 fluorescent lamps. The toggle switch was moved to engage (9) 16W LED light bars (nominal). For reasons discussed earlier, the actual power draw for the test case lighting measured lower than nominal wattage, at approximately 10.2W per four-foot light bar section. The measured reduction in power (demand savings) achieved with the installation of the LED light bars in this test is calculated to be 0.140 kW overall.

Figure 6.1 Cove Lighting Electric Demand Profile



[10] Complete electrical energy and demand savings calculations can be found in Appendix C-2.

Figures 6.2, 6.3, and 6.4 show recorded data from in-house testing of the medium-base incandescent lamps, compact fluorescent lamps and halogen MR16 as compared with the replacement LED luminaires. Measurements were recorded using the same electric demand data logger that was used on-site, and the comparison of the two hour-long test periods reveals the recorded reduction in electric demand.

Figure 6.2 Chandelier Lighting Electric Demand Profile

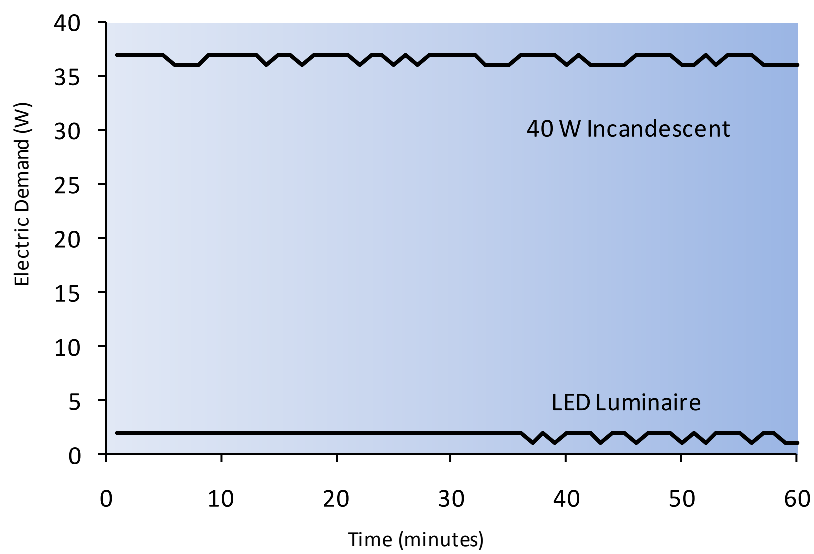


Figure 6.3 Recessed Downlight Lighting Electric Demand Profile

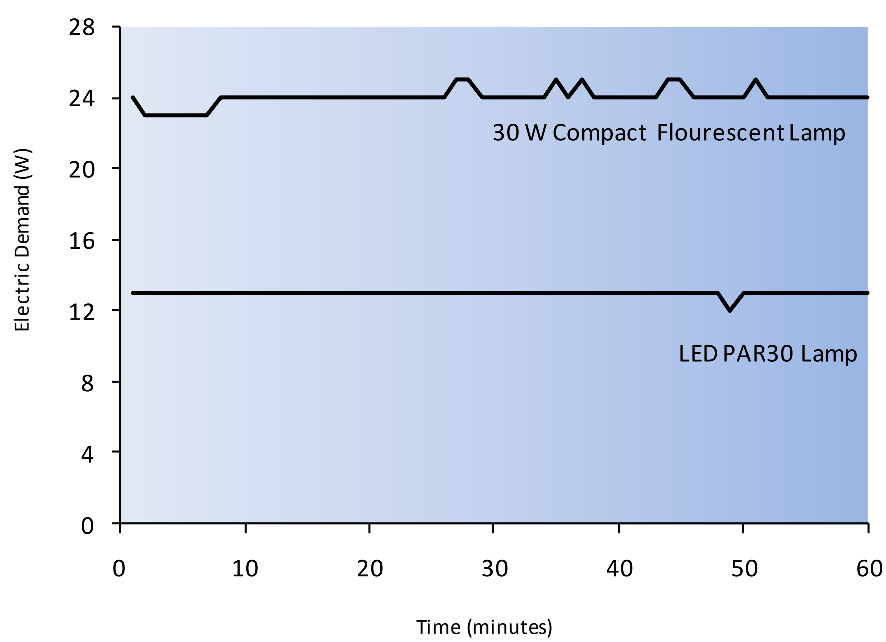
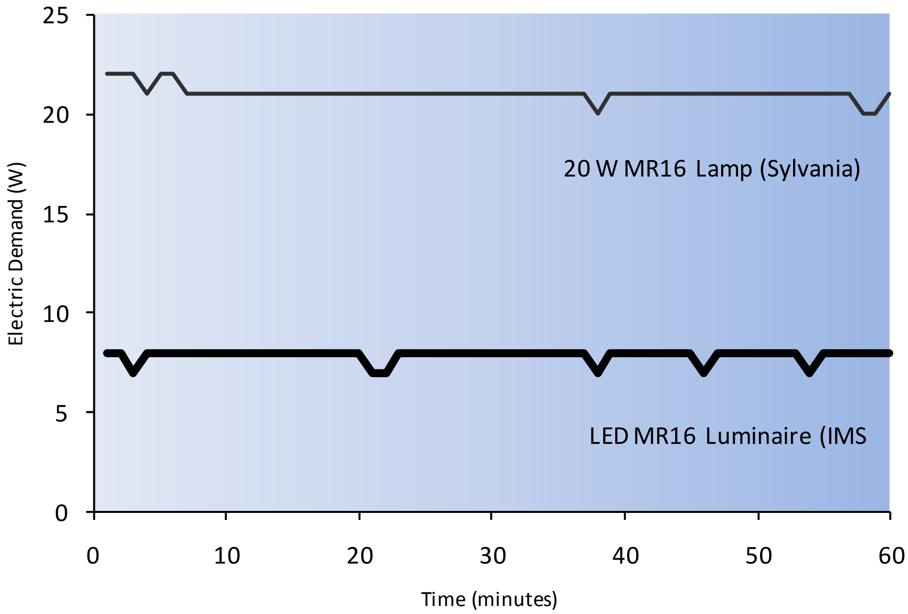


Figure 6.4 SPA MR-16 Lighting Electric Demand Profile



6.1.2 Demand Savings

For luminaires tested in-house, the total demand for each system was calculated by multiplying the per-lamp measured wattage by the quantity of that lamp type used in the field test. The difference in total calculated demand between base and test case is provided as the total electric demand savings for each application.

The total electric demand savings for the entire project were calculated at 1.772 kW. The average measured power and calculated demand savings per fixture and per application are summarized in Table 6.1.

Table 6.1 Project Demand Savings

Lighting Application/ Lighting System	Average Measured Power (kW)	Electric Demand Reduction/Luminaire (kW)	Total Electric Demand Savings (kW)
Spa Cove lighting			
(10) T8 fluorescent lamps	0.232		0.232
(9) LED light bars	0.092		0.092
Δ	0.140		0.140
Δ (%)	-	-	60.3%
Spa Seating MR-16 lighting			
(9) 20 W halogen MR16 lamps	-	0.021	0.189
(9) LED MR16 luminaires	-	0.008	0.072
Δ	-	0.013	0.117
Δ (%)	-	-	61.9%
Chandelier lighting			
(37) 40 W incandescent lamps	-	0.037	1.369
(37) LED luminaires	-	0.002	0.074
Δ	-	0.035	1.205
Δ (%)	-	-	94.6%
Hallway Down lighting			
(20) 30W CFL lamps	-	0.024	0.480
(20) LED PAR30 luminaires	-	0.013	0.260
Δ	-	0.011	0.220
Δ (%)	-	-	45.8%
	Total Project Demand Savings (kW)		1.772
	Total Project Demand Savings (%)		78.1%

The Plaza B hallway and chandelier fixtures are common areas that are open to the public at all times and were identified as continuously operated fixtures by facility personnel. Facility personnel indicated that fixtures located in the spa seating area operate approximately 18 hours per day. Measured data from the spa cove lighting suggest annualized operation for the cove lighting at approximately 8,165 hours per year. For all test areas, fixtures are judged to operate throughout the utility peak electricity rate period, which extends through the hours of 12 pm to 6 pm. The demand savings for this project are posted as coincident because they reduce the electric load during the utility peak demand period.

6.1.3 Annual Energy Savings

As described in the previous section, the hours of lighting system operation were reported by facilities staff, supported by on-site observations, and confirmed in the case of the spa cove, with measured data. No operational changes were made to the evaluated lighting systems during the course of the study.

Replacement of the four base-case lighting systems with test-case lighting resulted in a combined savings of 15,183 kWh per year in lighting energy savings. The savings associated with the chandelier project contribute the majority of the savings; this is because of the large scope of the project and the significant load reduction associated with each unit that was replaced.

Table 6.2 Project Energy Savings

Lighting Application/LED Lighting System	Total Electric Demand Savings (kW)	Operating Hours (hr/yr)	Annual Energy Savings (kWh/yr)
Spa Cove lighting (fluorescent) 9 LED light bars	0.140	8,165	1,143
Spa Seating Area lighting (halogen) 9 LED MR16 luminaires	0.117	6,570	769
Chandelier lighting (incandescent) 37 LED medium-based luminaires	1.205	8,760	11,344
Hallway Down lighting (compact fluorescent) 20 LED PAR 30 luminaires	0.220	8,760	1,927
	Total Project Annual Energy Savings (kWh/yr)		15,183
	Total Project Annual Energy Savings (%)		78.1%

6.2 Maintenance Savings

6.2.1 Effective Useful Life

Manufacturers usually specify an effective useful life (EUL) for LED lighting systems of at least 50,000 hours in product specifications. At the continuous operating hours (8,760 hr/yr) for most systems in this study, EUL calculates to 5.7 years, over twice the lifetime of the fluorescent lighting system, and over 16 times the lifetime of the incandescent lighting systems. The EUL calculates to 6.1 years for the cove lighting area and 7.6 years for the spa seating area.

Nonetheless, actual system lifetime for LED luminaires has yet to be verified by formal testing. LED performance and lifetime is heavily affected by drive current, thermal management, and ambient temperature. The DOE has reported testing at the LRC which demonstrates the significant deficit in lifetime of an LED source caused by an 11 °C difference in operating temperature.[11] This information is now dated, especially considering the quickening development of LED technology. It demonstrates the need for conservative estimates of EUL given the current instability of the market, lack of independent laboratory product testing, and influence of thermal management and ambient temperature.

Additionally, recent standard LM-80, issued by the IESNA in October 2008, defines end of life at 70% of initial lumen output. Therefore, manufacturer's estimates may require even further qualification before they can be readily employed to estimate the lifetime of a system.

6.2.2 Lifecycle Impacts

Replacement of fluorescent and incandescent lighting systems with LED lighting systems will typically result in avoided maintenance costs over the life of the new LED system. Since the LED lighting systems have a longer EUL, they will incur fewer equipment replacements and lower maintenance costs over life.

Maintenance savings are based on more than two cycles of avoided fluorescent lamp replacement and more than 16 cycles of avoided incandescent lamp replacement during the lifetime of the LED lighting system. Maintenance savings also assume that a small percentage (14.6 percent) of ballasts for the fluorescent lighting systems will fail annually; the percentage of actual failures will likely be higher or lower depending on the age of the ballasts.[12]

The avoided costs due to maintenance are calculated to average approximately $1,744/yr over the life cycle of the LED source. These savings are included in the project economics as shown in Table 1.3.

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[11] Building Technologies Program, 2007.

[12] The overall avoided maintenance costs during the expected life of the LED system are calculated in Appendix C-2.

6.3 Photometric Performance

Section 4.3.2 outlines how photometric field measurements were established for the various test areas. A summary of prominent project findings is included below; additional information is provided in Appendix B (photometric maps) and Appendix C (calculations).

6.3.1 Luminance

Figures 6.5 and 6.6 compare the luminous intensity of the baseline and LED luminaires for the chandeliers. Figure 6.5 shows the higher average levels of luminance achieved by the LED luminaires and Figure 6.6, indicating minimum and maximum values, shows less variance of results in the luminous intensity for the test case as compared to the base case.

Figure 6.5 Chandelier Luminance Measurements (Average)

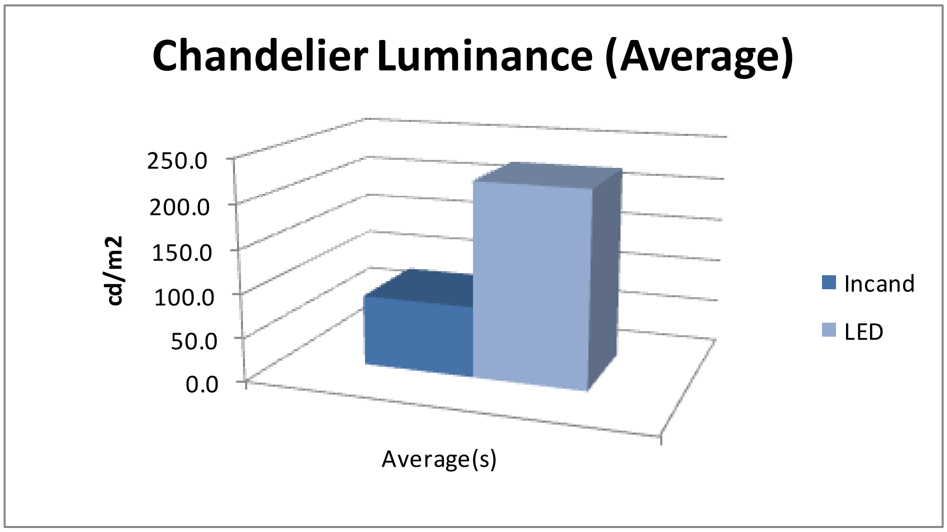
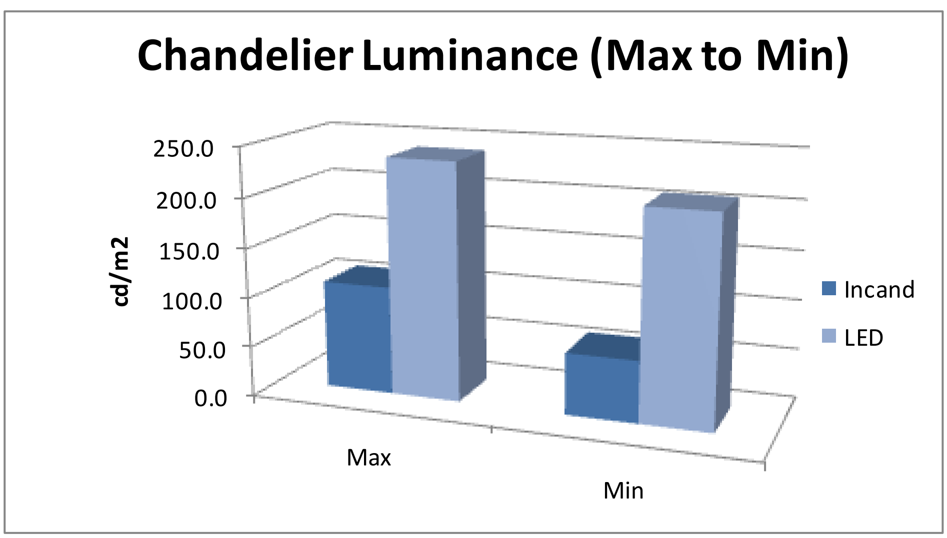


Figure 6.6 Chandelier Average Luminance Measurements (Max to Min)



6.3.2 Illuminance

Figures 6.7, 6.8, and 6.9 graphically compare average illuminance measurements for (3) of the baseline and LED lighting systems. Higher illuminance levels were measured for the base case fixtures than for the LED luminaires in all cases.

Figure 6.7 Cove Illuminance Measurements (Average)

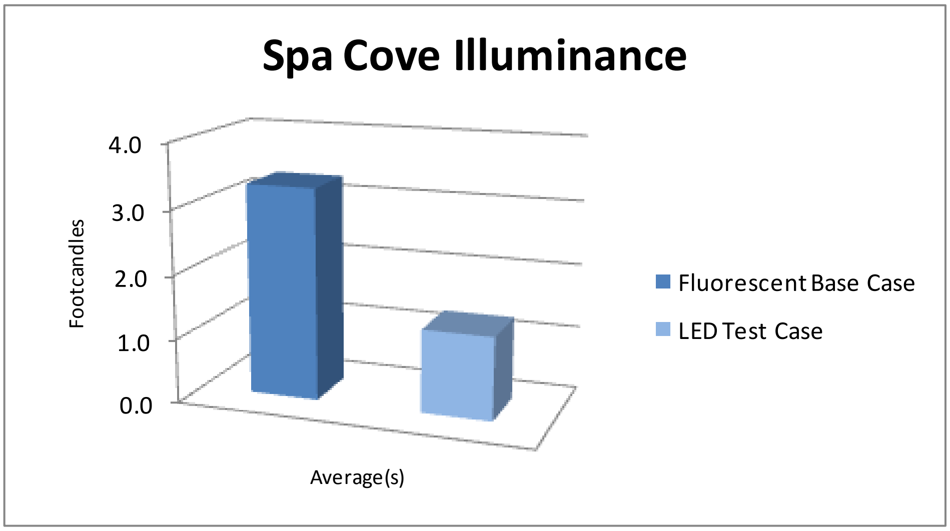


Figure 6.8 Spa Seating Illuminance Measurements (Average)

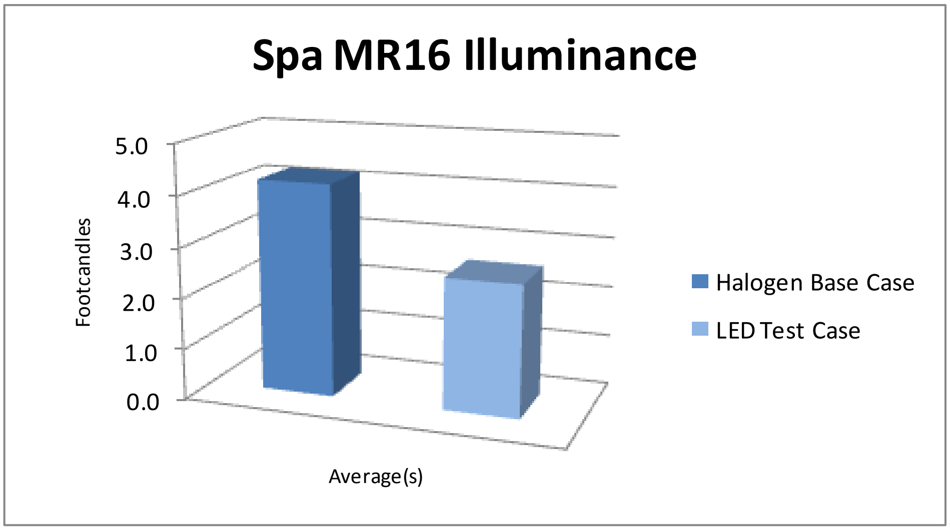
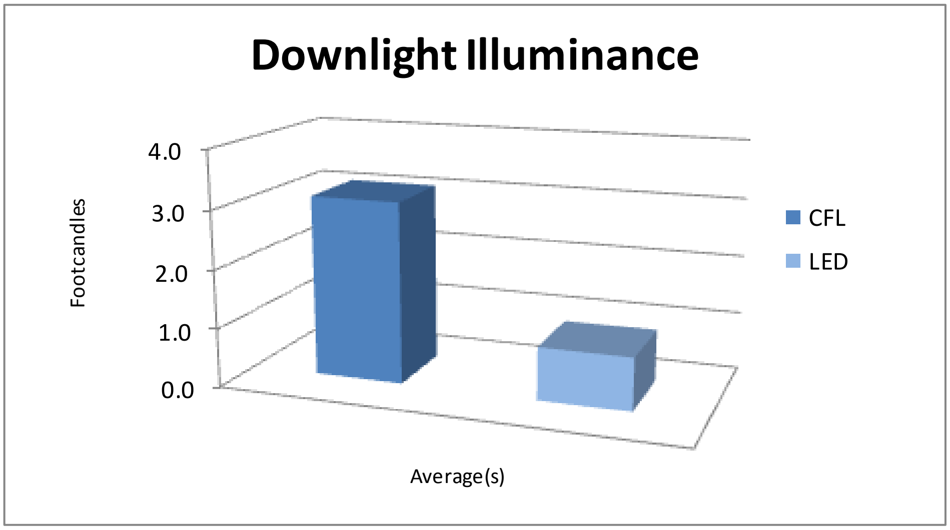


Figure 6.9 Hallway Downlight Illuminance Measurements (Average)



Figures 6.10 and 6.11 provide gradient contour plots illustrating approximate illuminance patterns for the base case and test case systems serving the spa seating area. The patterns suggest greater uniformity and overall intensity from the halogen relative to the LED.

Figure 6.10 Spa Seating Base Case Illuminance Pattern

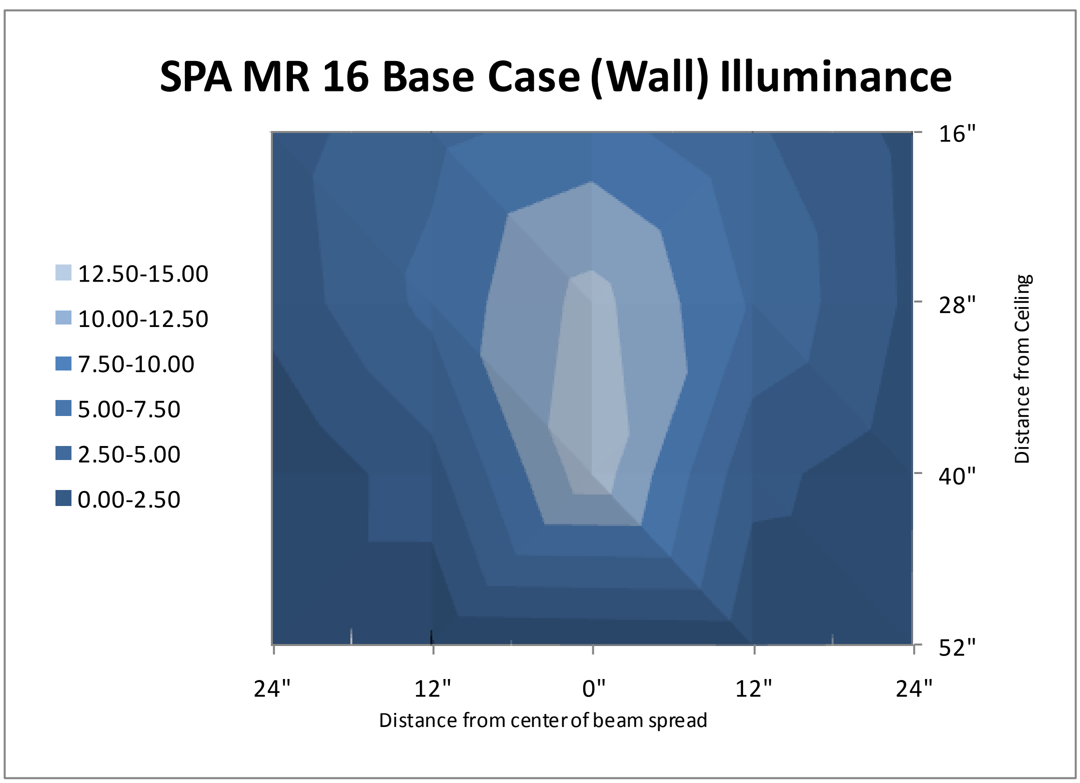
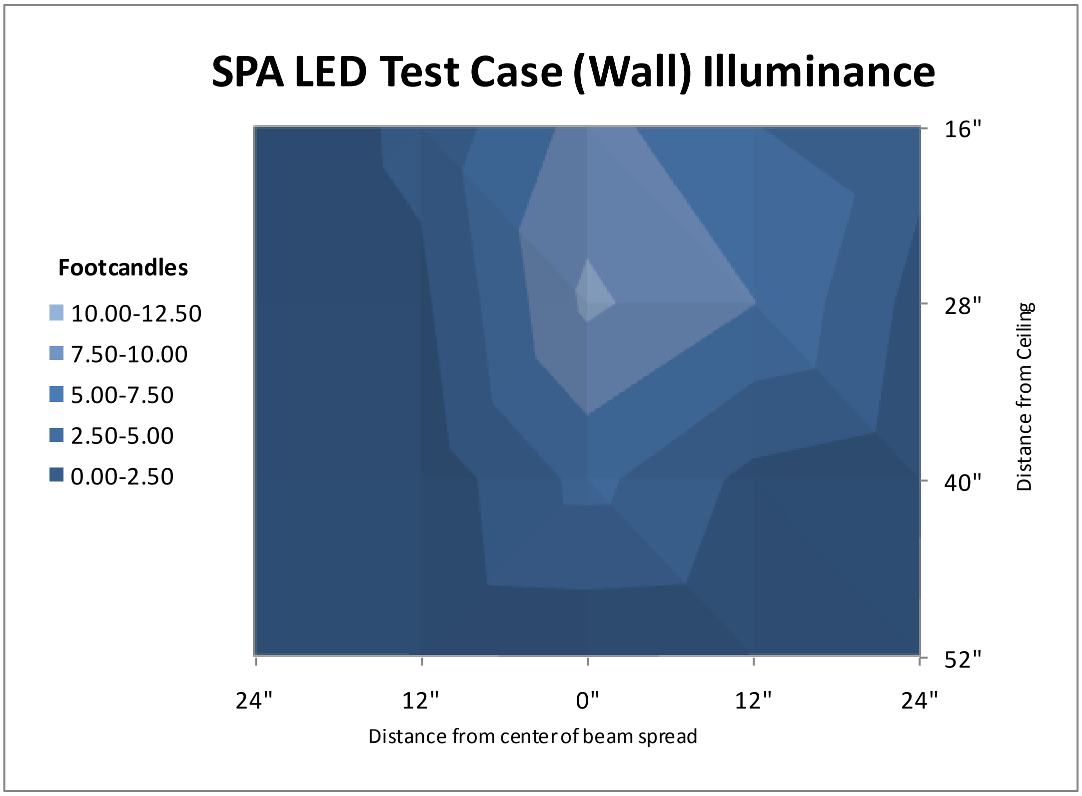


Figure 6.11 Spa Seating Test Case Illuminance Pattern



6.3.3 Correlated Color Temperature

The baseline halogen MR16 lamps used at the spa seating area recorded a CCT that varied between approximately 2,550 K and 3,000 K. The baseline MR16 halogen lamps were rated at 3,000 K. The replacement LED products were selected to match the baseline color temperature. Their CCT measured at approximately 2,850 K.

The base case incandescent lamps used in the chandelier registered about 2,450 K while the replacement LED sources measured 3,250 K. The cooler color of the replacement source was a barrier to customer acceptance, and the product was removed.

Color temperature was not raised as an issue with respect to the spa cove lighting. The average color temperature was measured at about 2,500 K for both the base and test case lighting systems.

In the downlight test, the color temperature associated with the CFL lighting was measured at about 2,550 K while for the LED replacement the value was about 3,100 K.

6.4 Incremental Cost for Materials and Installation

The projects undertaken for this demonstration and assessment replaced lighting systems with new LED lighting systems. For the retrofit of existing lighting systems with replacement lighting systems, the incremental cost of the project is the actual installed cost of the new lighting systems. The incremental cost basis for economic evaluation should be the actual installed cost. However, in this case, the material was provided at no cost to the end user, and the host customer provided the installation labor.

The manufacturer provided a sample cost basis for the materials used in the three test areas: LED light bars at $152.00 per four-foot light bar section [including power supply], MR16 replacements at $35.00 per unit, LED medium-base lamp replacements at $18.00 per unit, and LED PAR lamp replacements at $70.00 each.

The labor cost used in the economic analysis for light bar installation was based on an analysis of the labor hours (0.185 hours per unit) required for similar work performed during a previous application assessment performed for the Emerging Technologies Program, Report #0617. For the MR16 and medium-base lamp replacements, Means Electrical Cost Data was used to estimate the time required for lamp replacement. The labor cost for each project was calculated based on the total unit labor hours for the project multiplied by the burdened labor rate for an electrician performing work in the local area. See Table 1.3 for a summary of project economics.[13]

[13] Additional information is provided in Appendix C-2.

6.5 Customer Feedback

Feedback was gathered from employees from the Engineering and Property Operations departments. The survey asked respondents to rate their level of satisfaction with the replacement lighting system, with consideration of the following factors, among others:[14]

- Visual interest in the merchandise
- Amount of light
- Personal preference

As shown below, the response to the replacement lighting systems was generally favorable.

6.5.1 Chandelier (incandescent baseline)

Surveys completed: 3

Respondents reported a slight increase in the perceived level of light and were generally satisfied with the replacement LED lighting system. It was noted by one respondent that the "color temperature needs to be matched with lighting in nearby areas". Another survey participant noted a "big contrast to the other 2 chandeliers in the area", and that the new system was "well suited for display".

6.5.2 Plaza B Hallway (compact fluorescent baseline)

Surveys completed: 3

Respondents thought the replacement LED lighting system produced less light than the baseline lighting system and were on average only moderately satisfied with the replacement lighting system. One survey participant mentioned that "the new lights looked darker" while another respondent, indicated that the "lights need to be … brighter".

6.5.3 Spa cove and seating area lighting (fluorescent and MR16)

Surveys completed: 3

Reactions to both test areas were recorded on a single sheet. In general the respondents reports that the replacement systems created more visual interest and provided the same or more light than the base case lighting systems. Referring to the cove light application, one respondent noted that "the light fixture is not visible and it reflects the same light as the fluorescent bulb from the ceiling". Another survey participant characterized both the cove light application and the replacement MR16 system as "great".

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[14] The completed surveys are available as Appendix E.

7 Discussion

7.1 Site Coordination and Product Installation

As noted in Section 4.1, “Project Background and Timeline”, PG&E, the project host, and project evaluation team coordinated efforts to identify the test sites and project parameters. This process identified base case lighting for replacement, and LED product manufacturers and equipment for the test case. The host customer installed the LED products in the test areas in accordance with project requirements so that the project evaluation team could conduct base and test case measurements. For the chandelier, and downlight lamp replacements, the installation was simply a one-for-one replacement of screw-based lamps in their current orientation.

With the MR16 replacements, the recessed fixtures permit adjustment of the lamp to optimize the beam for a specific application. Due to differences in beam characteristics between the base and test case luminaires, it is likely that some adjustments were made by the installer in the process of attempting to balance the effect of lighting on the seating area wall. Overall, this re-aiming affects the visual appearance of the wall but probably does not affect the overall illuminance levels.

As discussed in Section 4.2, “Product Information and Installation”, site personnel installed the LED cove lighting as an alternate rather than as a replacement lighting system for the pre-existing fluorescents. The base case linear fluorescent lighting system consists of a typical cove configuration of continuous T8 fluorescent lamps mounted in the cove, utilizing white enamel reflectors to direct light out of the cove, mainly towards the upper portion of the elevator wall. The test case LED lightbars were set end-to-end on top of the fluorescent fixture housing cove encasement in such a way that neither system impacts the lighting distribution provided by the other. The LED system is pointed straight towards the ceiling rather than optimally aimed to more completely direct light out of the cove. Also, the LED system was equipped with one Advance driver that was rated at a maximum of 100W, which limited the maximum power available to the test case system and caused the LED light bars to be under driven relative to their maximum rated power. The installation included a two-way toggle switch so that one system would be engaged at a time. Both systems and the toggle switch remained in place following conclusion of the study.

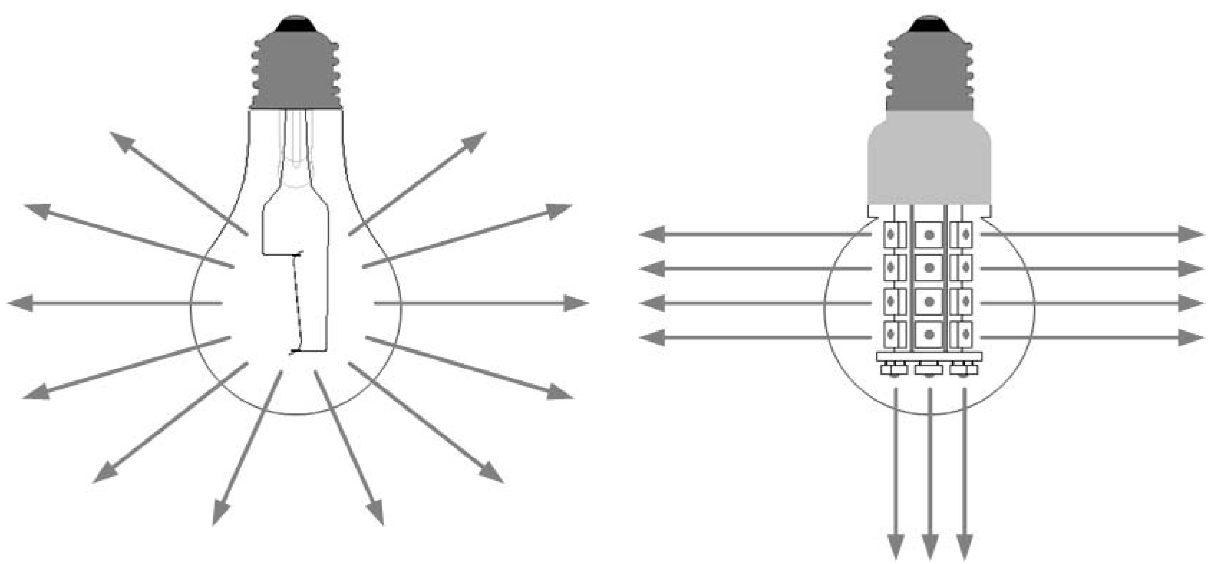
7.2 Product Evaluation

7.2.1 Comparison of Baseline and LED Lighting System Performance

Luminance measurements for the chandelier project are included in Table 7.1 on the following page. Measurements were taken on the surface of the chandelier crystals. Higher luminance levels were measured for the LED replacement lamps than for the incandescent base case. The LED assembly is a prototype with no available photometric report; therefore, a formal comparison of optics is not possible.

The existing 40W A-19 incandescent light bulb is considered an omni-directional source.[15] In contrast, the replacement source is designed to distribute light in a circular pattern at right angles to the base orientation, as well as straight down as shown in Figure 7.1.

Figure 7.1 Omni-directional vs. Directional Light Source



The improved luminance values for the test case suggest that the directional nature of the LED work in favor of the replacement, which directs light to a greater extent at the crystals than does the incandescent base case. Given laboratory results of tests performed on similar products, as detailed in Section 7.2.5, the enhanced levels of luminance observed in this study likely result from a fortuitous match of product and circumstances which could be characterized as a successful niche application. However, the color temperature of the test case was significantly higher than the base case, and unacceptable to the project host.

15 CALiPER Benchmark Report, 2008. pg 2.

Table 7.1 compares the base and test case illuminance value measurements. Each test indicated a reduction in average illuminance for the test case system as noted.

Table 7.1 Test Area(s) System Performance

Test Area	Photometric Measurement	Baseline Incandescent Lamps	Replacement LED Luminaires	∆ Average (%)
LED Chandelier Lighting	Luminance (cd/m^2)	81.8	208.3	173%
LED Downlight	Illuminance (fc)	3.0	0.9	-71%
LED Fluorescent Cove	Illuminance (fc)	3.3	1.3	-61%
Spa LED MR16	Illuminance (fc)	4.2	2.6	-38%

7.2.2 Manufacturer's Claims and Product Performance

Since LED lighting technology is still emerging and evolving, much inconsistency has been observed in the industry. Even as of 2008, testing results are at variance with manufacturer's claims:

> *"CALiPER testing continues to reveal that many SSL [solid-state lighting] products do not meet manufacturer performance claims, although a few high-performing products are emerging on the market and definite progress can be seen in some product categories."*[16]

Round 4 of CALiPER testing, in January of 2008, revealed about nine out of 15 SSL products tested that, "information published by manufacturers regarding product output and/or efficacy overstated performance (by factors ranging from 30–600%)."[17]

Similarly Round 5 of CALiPER testing, in May of 2008, noted that of two A-lamp tested, both "products failed to meet the performance claims made by the manufacturers in product literature."[18]

Since independent laboratory testing of the products used in this assessment was not available (see Section 7.2.3) comparison between product specifications and project results are difficult to draw.

[16] CALiPER Round 6
[17] CALiPER Round 4
[18] CALiPER Round 5

Table 7.2 illustrates the manufacturer's published input power data, where available, as compared to the average measured electric demand. The power draw per unit light bar is significantly below published values because the lightbars are underdriven due to the driver configuration. Also, the MR16 luminaires draw more power than expected.

Table 7.2 Demand Performance

Lighting System	Reported Electric Demand (W)	Average Measured Electric Demand (W)
LEDPower: LED Light Bar 4' section	16	10.2
LEDPower Incandescent Replacement	N/A	2
IMS: MR16 Luminaire	4.7	8
LEDPower PAR30 LED Luminaire	13	13

7.2.3 Independent Product Laboratory Testing

The manufacturers were unable to provide independent laboratory test data for the products tested in this study.

Independent testing usually includes the measure of total luminous flux, input electrical power, luminaire efficacy, luminous intensity distribution, lumen maintenance, correlated color temperature, and other standardized performance characteristics.

Independently verified distribution data would have been particularly useful in interpreting field measurements and end user perceptions. Since LED lighting system performance is often amplified by the accurate delivery of light from source to application, this information is particularly useful. Independent laboratory efficacy ratings would also have been integral for a thorough evaluation of luminaire efficacy as a comparison with manufacturer's claims. It is recommended for future studies of this type that lighting samples be provided to independent agencies for laboratory testing during the initial phases of implementation. IESNA LM-79-08 details electrical and photometric testing methodology specifically addressed to the unique requirements of solid-state lighting.[19] This standard is quickly being adopted by the industry, and, along with IESNA-80-08 and ANSI C78.377-2008, which address lumen depreciation and chromaticity and will be necessary in the future for the evaluation of LED lighting systems.

[19] IESNA, 2008

7.2.4 Luminaire Performance

Efficacy is the standard definition for lighting performance, defined as "the ratio of light from a lamp to the electrical power consumed, including ballast losses, expressed as lumens per watt." [20]

This study approaches lighting performance differently, since only field measurements of photometric and electric demand data were available. Illuminance ratings were adopted as the primary indicator of luminaire performance, as this rating reflects the incident light important to customer and retailer perception. Illuminance measurements also offer insight into luminaire optics and other environmental factors.

Table 7.3 on the following page summarizes the illuminance and electric demand performance of the three tests where illuminance values are presented. No performance comparisons are drawn for the chandelier test where only luminance readings were performed.

Table 7.3 Summary of Luminaire Performance

Lighting System	∆ Average Illuminance (%)	∆ Electric Demand (%)
Hallway lighting LED Par30 luminaire replaces 30W CFL	(71%)	(46%)
Spa Cove lighting LED lightbars replace T8 fluorescent cove lighting	(61%)	(60%)
Spa Seating area LED MR-16 luminaire replaces 20W halogen MR-16 lamp	(38%)	(62%)

7.2.5 Comparison of Luminaire Performance against DOE CALiPER Testing

Although no LED MR-16 luminaire tested by the CALiPER program directly matches the luminaires tested in this study, general comparisons can be drawn regarding performance trends. As of publication of this report, six rounds of CALiPER testing have been published with efficacy results for various LED applications and their "standard" (fluorescent or incandescent) counterparts.

Table 7.4 provides a representation of CALiPER testing used as points of comparison in the discussion of system performance. Since few products have been tested *in situ*, this sample data takes bare lamp photometric readings as indications of the expected performance of the products used in this study. In addition, comparisons of light output between CALiPER data (luminous flux, measured in lumens) and the measurements recorded in this field study (luminous exitance, measured in footcandles) are limited.

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[20] Nebraska Government n.d.

Table 7.4 DOE CALiPER Testing of LED MR16 and Light Bar Luminaires

Test Description	DOE CALiPER Test ID	Efficacy (lm/W) difference* (%)	Demand difference* (%)	Initial lumen output difference* (%)
SSL Light Bars (32 W T8 Fluorescent)	07-56, 08-17, 08-19, 08-37	(59%)	(36%)	(73%)
SSL MR16 (20 W Halogen MR16)	07-53, 07-59, 07-64, 07-17, 07-58, 08-07, 08-83, 08-84, 08-97, 08-98	96%	(80%)	(64%)
SSL Decorative (40 W A-19 Incandescent)	07-06, 07-12, 07-23, 08-03, 08-25, 08-55, 08-80, 08-81, 08-82, 08-92	226%	(36%)	(57%)

* Results represent mean data from entire testing series. All values are rounded to the nearest integer.

Round 5 of the program compared four different 4' LED light bars against a baseline of 4' 32 W linear fluorescent T8 lamps. Generally, these results demonstrate higher reductions in initial lumen output and lower reductions in electric demand as compared to more directional fixtures like the MR16 luminaires

As of Round 6, ten different MR-16 LED luminaires have been tested alongside six baseline 20 W halogen MR-16 lamps. Testing concludes that, although the LED luminaires have less average lumen output compared to the 20 W halogen lamps, lumen output as well as efficacy (lm/W) of the LEDs increased as testing rounds progressed. The efficacy of the LEDs ranges between two and three times the average efficacy of the halogen lamps (~25 lm/W as compared to ~12 lm/W). Nonetheless, these efficacy levels do not reach the levels claimed by the product manufacturers.

Among (10) independent tests of replacement LED A-lamps, efficacy results range from 13 lm/W to as high as 62 lm/*W.* [21] Field testing of the luminaires generally agree with the performance trends revealed by CALiPER testing.

[21] CALiPER Benchmark, 2008

7.3 Measure Feasibility and Market Potential

7.3.1 Current Feasibility and Potential

The measures are technically feasible but range in cost-effectiveness at current market conditions. Projected simple payback periods (including the impact of maintenance savings) are less than one year for the chandelier incandescent and spa MR16 lighting replacements. The down light compact fluorescent replacement project has a three-year simple payback and the fluorescent cove lighting simple payback period is approximately five years, which is somewhat less than EUL.[22]

The reduction of energy use in the lodging and hospitality sector can be a challenging task because services are driven by a need for customer satisfaction, in turn dependent on their visual and physical comfort. Although lighting does not account for the main portion of a hotel's energy use, significant savings can be accomplished through energy efficient lighting technologies. Renovations to existing hotels—replacement of inefficient boilers, lighting, and other systems—can save up to 30 percent on annual energy costs.[23]

This demonstration project achieved a reduction in lighting energy usage, while maintaining customer acceptance. The adoption of this technology in the lodging and hospitality industry depends mainly on its integration with each building's architecture and interior design and its ability to provide a comfortable and welcoming customer environment. LED technology offers multiple design solutions that can help create the atmosphere required by each specific lighting application.

7.3.2 Cost and Performance Projections

Widespread adoption of solid-state lighting is dependent on the suitability of application and cost effectiveness. Suitability issues are largely performance issues, including color, distribution, product life, and power requirement.

The industry generally measures lighting cost effectiveness in terms of the first cost associated with a given level of lumen output, as reported in dollars per kilolumen ($/klm). In reporting and projecting future trends in cost effectiveness, this metric accounts for change in production cost and source efficacy. The potential of LED technology for rapid change is expressed in general terms by Haitz's Law, which predicts that every 10 years efficacy will increase by a factor of 20 and cost will decrease by a factor of 10.

The DOE projects the market penetration for white LED lighting applications based on technological development as well as materials and manufacturing cost improvements. The

[22] These estimates are based on an effective useful life of 50,000 hours and associated maintenance savings. See Appendix C for cost-effectiveness calculations.

[23] Building Technologies Program, 2008

modeling system is based on the state of the industry in 2001, at which time market penetration was defined as zero, and the cost of medium CRI LED technology was set at $275/klm.[24] The most conservative projection for 2010 predicted efficacy would reach 45 lm/W and cost would reduce to $36/klm; the report's most conservative scenario predicted a cost of approximately $8/klm by 2020, while the least conservative model predicted a cost of approximately $0.50/klm.[25]

A comparison of the predictive models can be drawn against the current state of the industry as a partial validation of the models. LED efficacy testing in accordance with LM-79 protocol has already exceeded the predicted efficacy of 45 lm/W in numerous applications including a 2007 DOE typical performance value of 54 lm/W for medium CRI LED technology.[26]

The same multi-year program plan for solid-state lighting research and development, issued by the DOE in 2008, offers updated pricing prediction models. These models demonstrate that the 2001 study's projected performance has already been exceeded; the pricing for a 1 W cool-white LED source was reported to be $35/klm in 2006 and $25/klm in 2007: cost reductions beyond Little's prediction of $36/klm in 2010. This more recent DOE model further predicts LED source technology to reach price points of $10/klm in 2010, $5/klm in 2012, and $2/klm in 2015. It should be noted, however, that the full price of an LED luminaire (~$100/klm in 2008) is greater than that of the device.[27]

7.4 Future Technology Improvements

7.4.1 Increasing Industry Standardization

The development of LED lighting standards is continuing at a rapid pace; 2008 saw the release of:

- ANSI C78-377-2008. *Specifications for the Chromaticity of Solid-State Lighting Products for Electric Lamps*. February 2008.
- IESNA LM-79. *Approved Method: Electrical and Photometric Testing of Solid-State Lighting Products*. May 2008.
- IESNA LM-80. *Approved Method for Measuring Lumen Depreciation of LED Light Sources*. October 2008.

Furthermore, ENERGY STAR criteria for solid-state lighting luminaries, which went into effect on September 30, 2008, stipulate minimum linear flux levels. Importantly, this

[24] CRI becomes a determining factor in cost effectiveness due to the expense of the phosphor coating needed to achieve a given CRI level.

[25] Little, 2001

[26] Navigant, 2008

[27] *Ibid.*

represents the increasing acceptance of the directionality and focus of LED lighting, which bears relevance to this application study.

Major standards in development include IESNA RP-16 (Definitions), ANSI C82-.XX1 (Power Supply), and UL 8750 LED (Safety). These standards will help unite the industry's offerings in terms of quality and performance, which will result in a greater reliability of performance in the marketplace.

7.4.2 Projected Improvements in Manufacturing and Materials Science

LED lighting is a rapidly advancing technology. It is anticipated that on-going improvements to the LED technology, power supplies and installation methods will lead to continuing price reductions and increased energy savings. Manufacturers are working to improve thermal efficiency to enhance expected life and light output.

The combination of advancements in materials science, luminaire design, technology adoption, and market stabilization is expected to result in continued improvement in the viability and cost-effectiveness of LED lighting technology.

8 Conclusions

A full-service hospitality center provides a challenging test environment in that the laboratory is also a place of business, thus any changes in operations or appearance are scrutinized by hotelier and customer alike. The survey results support general acceptance of the demonstration project by the project host. The generally favorable customer survey responses align with findings reported in the companion study, PG&E Application Assessment Report #0717. This bolsters the suggestion made in that previous study that one of the major barriers to implementation, user satisfaction, is surmountable for the application.

The other major traditional barrier to implementation is cost-effectiveness. The data supports a significant savings opportunity for the applications included in this assessment; however, the level of cost-effectiveness varies. The direct replacement of MR-16 and decorative medium-base incandescent lamps were cost effective in this demonstration: the cost of implementation was significantly less than the value of the energy savings available over the product's expected life. In the case of the fluorescent cove lighting and hallway compact fluorescent downlight applications, the cost of implementation fell below the combined value of the energy and maintenance savings available over the expected life of the product.

It is important to note that the cost-effectiveness of LED technology in these types of applications will vary according to actual site conditions. These include actual baseline lighting system configurations, lighting wattage, system operating hours, and utility rate structure. Decorative accent and focused directional applications, which permit reduced light output relative to the baseline lighting systems, produce higher levels of energy savings than those applications for which no reduction in light output is warranted. The chandelier and spa seating lighting systems are examples of the types of applications that are more likely to be cost effective than applications that provide ambient lighting.

In general, it is expected that the cost-effectiveness barrier will be overcome with maturing market conditions. Various incentive programs could also accelerate cost-effectiveness.

PG&E uses this and other Emerging Technologies assessments to support the 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.

9 Recommendations for Future Work

There is a need for independent research to further develop the performance, potential application, and adoption of LED lighting sources. Recent implementation of standards for LED chromaticity, electrical testing, photometry, and lumen depreciation have provided the industry with a set of laboratory test protocols and metrics. The development of these standards marks the beginning of a maturing solid-sate lighting technology by leveling performance metrics in the laboratory.

Nonetheless, this study outlines areas in two general categories that would help to accelerate the adoption of LED light sources. These recommendations are restated from the companion study, PG&E Application Assessment Report #0717, which was conducted simultaneously to this effort and under similar conditions.

9.1 Field Performance

The cornerstone of customer acceptance and technology adoption is field performance; evaluation of field performance is the domain of the application assessment study. Two substantial, broad areas of performance are suggested by customer concerns and by the availability of emerging standards.

1) *Lumen depreciation in solid-state lighting.*
   The project team noted the implications of lumen depreciation in LED sources to lifecycle cost analysis and customer adoption. While life is currently assessed by laboratory testing, an extended in-field study would be a useful tool in assessing the actual long-term performance of LED light sources, especially in respect to manufacturer's claims. A thorough study would require several years, but would yield actual results on the implications of alterations to drive current and thermal management to lumen depreciation. These implications relate to life cycle cost and customer acceptance.

2) *Conventional and LED lighting system design.*
   Detailed photometric analysis of the effect of the nano-optics would offer insight into the proper fixture placement and orientation. There is a lot of variation in the current market in regards to form factor and optical design. Solid-state lighting technology differs so inherently from conventional lighting that a study would offer an initial outline of design guidelines for these emerging systems. Results would benefit application assessment and other in-field studies, while offering preliminary design guidance to early adopters.

9.2 Market Assessment

Equally important to market acceptance and adoption is the perception of value. Two related areas in market research are recommended for further evaluation.

1) *Trends and projections in the end-user cost of LED lighting systems.*
   While Section 7.3.2 provides general estimates of future affordability from DOE research, this data is primarily based upon the cost of the source material. An analysis of recent cost trends in PG&E service territory would be useful to the utility in projecting the short term pricing of LED lighting, including consideration of other system components, and to estimate the end-user demand for LED products.

2) *End-user reaction to and evaluation of LED lighting systems.*
   The design and implementation of expanded end-user surveys would provide valuable information on the potential for equipment adoption. Though surveys on perception and aesthetics were completed by project hosts and customers, systematic surveys would provide more generalized results and could address questions related to cost and value.

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Appendices

Appendix A

Test Protocol

PG&E Emerging Technologies Lighting Demonstration Project
LED Low Wattage Lighting (CWA 07 CEE-T-4376)
Testing and Monitoring Plan - Hilton

Testing Protocol for Light Emitting Diode (LED) Lighting in Low Wattage Applications

I. Objective

This test protocol is intended to define a test procedure that will be applied to LED lighting in various low wattage applications as part of the Emerging Technologies Program evaluation process. Testing will consist of first recording existing (baseline) conditions, then recording conditions following the implementation of the emerging technology.

II. Project Design Plan

Prior to conducting on-site testing, a project design plan will be required that minimally indicates the quantity of fixtures and specific locations for each test. The responsibility for developing the project design plan will be as agreed between project stakeholders. The project design plan should be made available to Pacific Gas and Electric Company (PG&E), EMCOR Energy Services (EES), the site, the vendor, and the installer prior to initiation of baseline testing.

III. Proposed Testing Areas

1. LED replacement lighting systems will be tested at various locations in the Hilton Hotel located at 333 O'Farrell Street, San Francisco, California as follows:
    a. Screw-based low wattage parabolic reflector (PAR) type LED lamps will replace halogen and compact fluorescent down-lights in the side hall and side entry adjacent to the Plaza B Meeting Room. Approximately eight PL-13 fixtures controlled by one switch are located in the hallway between Plaza Rooms A and B. Also, approximately six halogen fixtures are located in the room immediately outside of Plaza Room B. Five of the halogen fixtures are controlled by two switches.
    b. Screw-based, low wattage, decorative LED lamps will replace incandescent lamps in the center chandelier located in the main hall leading to the Plaza meeting rooms from the lobby. Each chandelier uses approximately thirty-three 40-Watt incandescent lamps.
    c. Continuous LED light bars will replace fluorescent lighting installed in the “cove” fixtures located over the bank of elevators serving the lower level “Spa” area. The length of the cove is approximately 38 feet 6 inches.
    d. Approximately six MR-16 style LED lamps will replace an equal quantity of low voltage MR-16s located in the lower level Spa area.

IV. Performance Issues

The following issues have been recognized as critical to energy savings and long-term customer acceptance.

- Power consumption
- Lifetime and reliability
- Brightness and light quality

V. Setup Protocol

1. Request, receive, and review the Project Design Plan prior to site visit.
2. Existing lamps serving the test area must be replaced prior to baseline testing. The purpose for the adjustment to the baseline condition is to ensure that the light output of both existing and replacement light sources is compared at the same point of depreciation, in this case as "new".
    a. Fluorescent lamps must be replaced with new fluorescent lamps of wattage equivalent to the existing case, and the new lamps must be "burned in" for at least 100 hours to stabilize the baseline condition.
    b. Failed ballasts in test areas should likewise be replaced.
    c. Incandescent, halogen, and low voltage lamps must be replaced with new lamps of wattage equivalent to the existing case.

3. Prior to taking lighting measurements, EES will designate measurement points in each test area by marking out a grid comprising at least three rows and three columns with an identifiable marker.
    a. The actual measurement grids will be determined at the time the tests are performed and will include vertical and/or horizontal components depending on the visual tasks being performed (e.g., circulation, signage, display functions).
    b. EES will take a digital image of each test area and measurements will be superimposed onto the digital image in order to create a measurement map.

4. Prior to taking lighting measurements, EES will document the specific measures taken to isolate the effect of changes to the test lighting systems from general lighting systems that are not subject to change.

VI. Tests Performed

The following tests shall be performed on existing lighting systems and the emerging technology (LED), with the exception of Task 5 of the test. Task 5 will be performed only for the emerging technology.

1. Validate Scope of Project
    a. Base Case: Refer to the Project Design Plan. Validate and record existing light fixture types, quantities, and locations that are intended for replacement or retrofit.
    b. Test Case: Refer to the Project Design Plan. Validate and record light fixture types, quantities, and locations of new LED sources.

2. Measure Luminance
    a. Measure luminance values on the test grid using a Konica Minolta LS100 Luminance Meter.
    b. Record and report the characteristics of the surface of objects on which the luminance measurements were performed, and the distance at which the measurements were taken.
    c. Luminance values will be indicated on luminance maps.

3. Measure Vertical and/or Horizontal Illuminance
   a. Measure and record illuminance values on the test grid area using a Konica Minolta CL200 Chroma Meter.
   b. Measurements will be taken in accordance with viewing angles applicable to the task typically performed.

4. Determine Correlated Color Temperature
   a. Measure and record correlated color temperature on the test grid using a Konica Minolta CL200 Chroma Meter.

5. Determine Color Rendering Index (CRI)
   a. PG&E will coordinate with the California Lighting Technology Center (CLTC) to provide a sample lighting source to the CLTC lab for testing.
   b. EES will coordinate with the CLTC to obtain CRI test results and incorporate results into the report.

6. Determine Power Usage and System Run-Time (Isolated Circuits)
   a. Work with the host site to identify the circuit or circuits powering the test area. Note that in some instances, the test area may include only a portion of a circuit; in others, the test area may include more than one circuit. Selection of the circuit or circuits to monitor will be a field decision made at the time that the monitoring equipment is configured.
   b. EES will note all loads present on the circuit or circuits being monitored, and will also note which additional circuits, if any, are part of the test area but are not being monitored.
   c. Oversee installation of a Dent Elite-Pro data logger by a licensed electrician. System power draw for existing fixtures and the emerging technology (LED) will each be monitored for approximately 7 days.
   d. EES will note the dates of the system changeover.
   e. Oversee removal of the Dent Elite-Pro and evaluate the data collected.

7. Spot Measure and Run-time Logging (Non-Isolated Circuits)
   a. Where EES determines that lighting circuits do not correlate well with the test fixtures, perform and record spot power measurements for selected test area fixtures.
   b. Install lighting loggers at test area light fixtures to record fixture runtime operating information.

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8. Photo Documentation
   a. For each lighting system being evaluated, use high resolution digital photography to document baseline lighting systems, including the effect of lighting on selected task areas, visual images of the light source as applicable, and general images of the surrounding area.

9. Customer Satisfaction
    a. EES will draft a brief written survey to help determine the level of customer satisfaction with the test installation.
    b. EES will present the survey to the host site management for approval.
    c. Upon management's approval, the survey will be administered to the host site's staff, management, and maintenance personnel.

VII. Evaluation

Upon completion of testing, collected data will be evaluated to determine the energy savings and lighting performance of the emerging technology.

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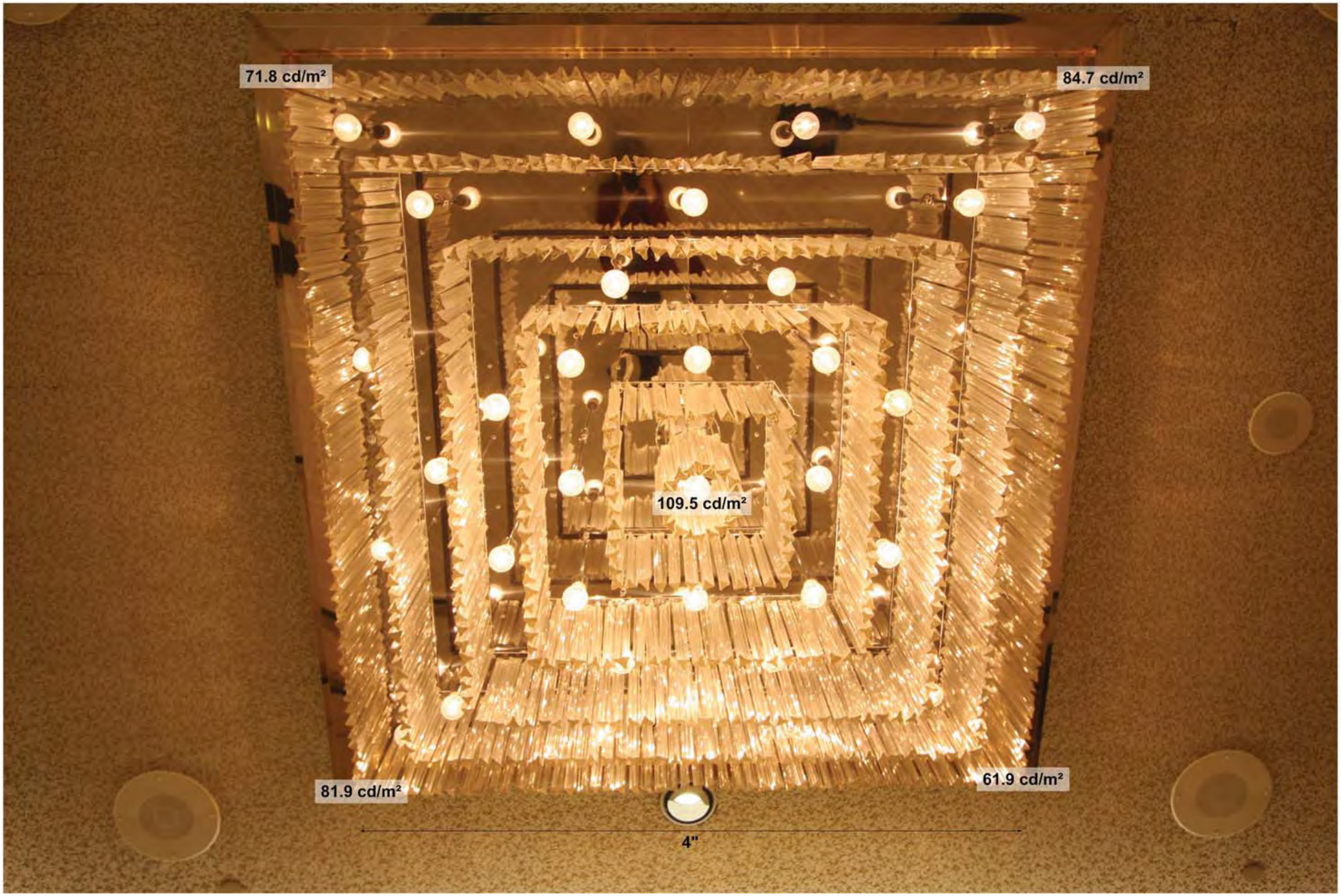
Appendix B

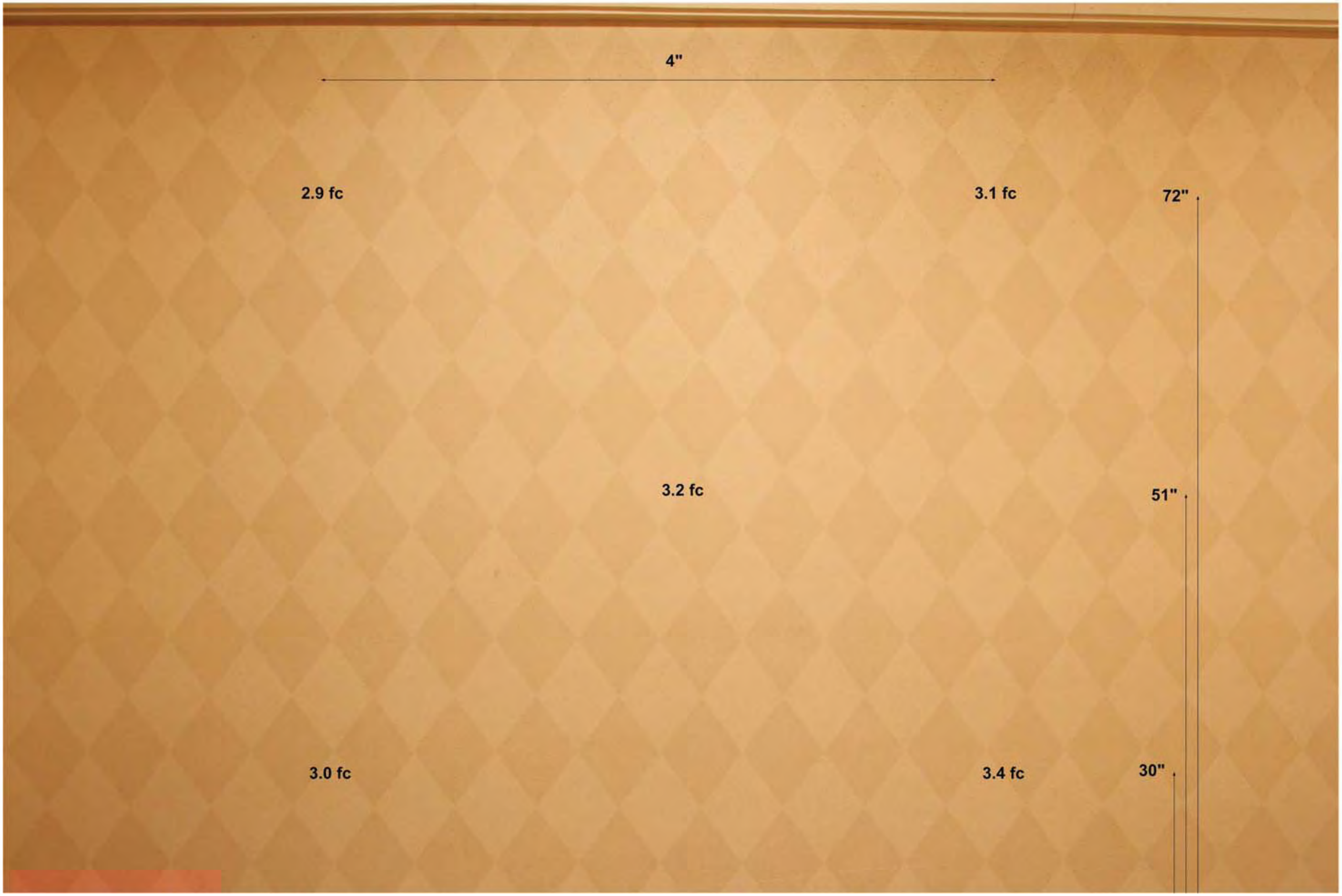
Luminance and Illuminance Maps

Base Case: Chandelier Luminance

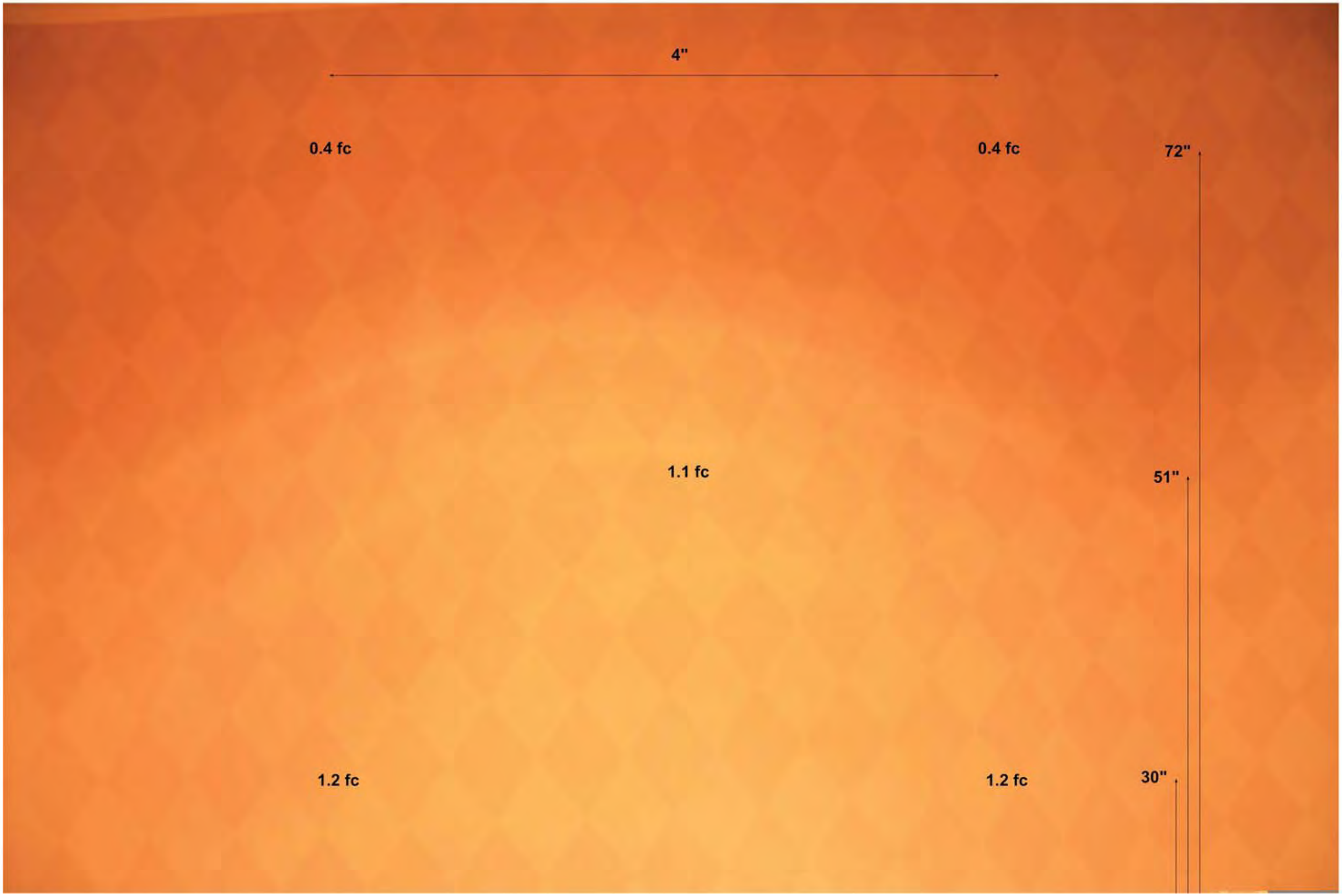


Test Case: Chandelier Luminance

Base Case: Hallway Illuminance



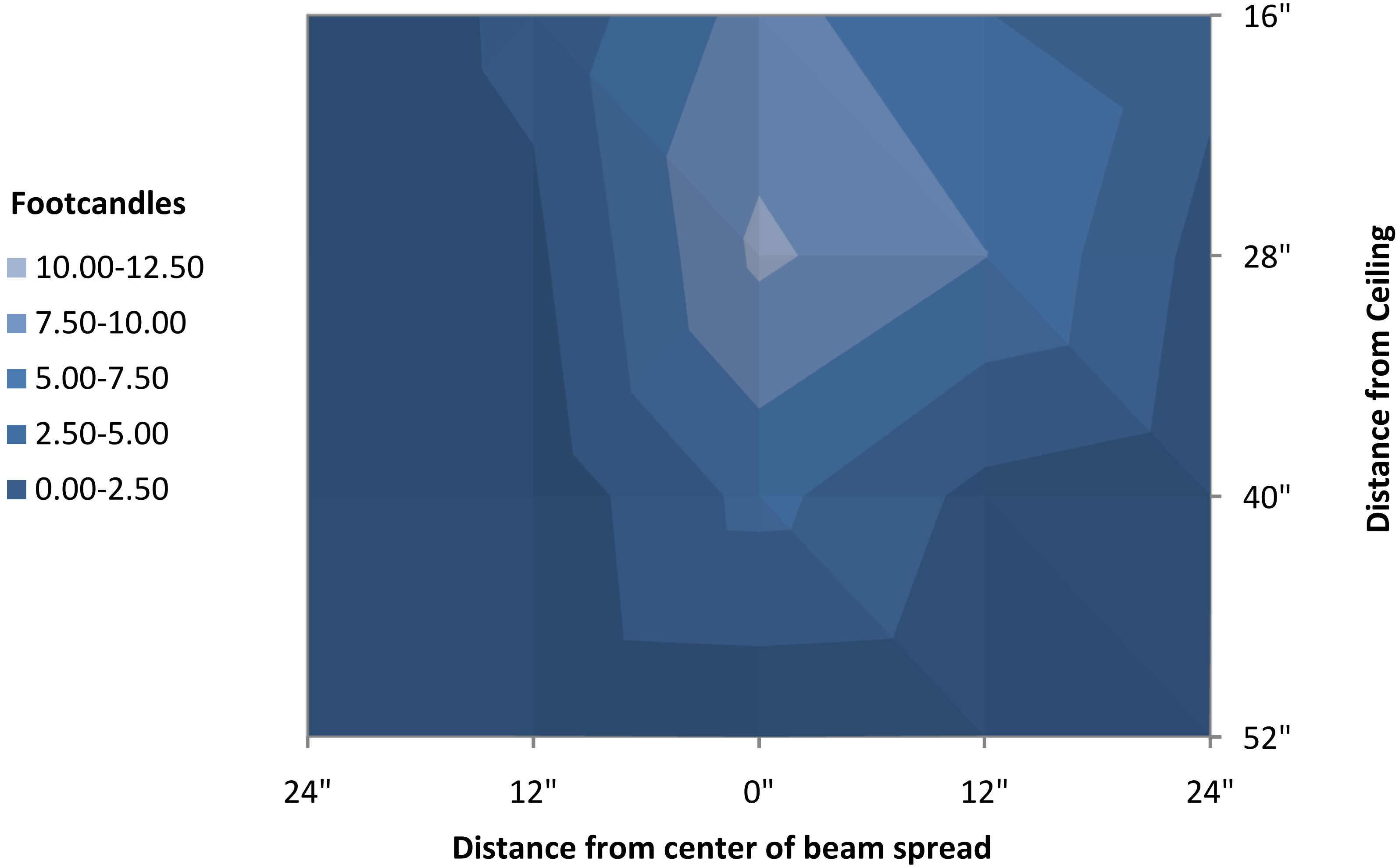
Test Case: Hallway Illuminance



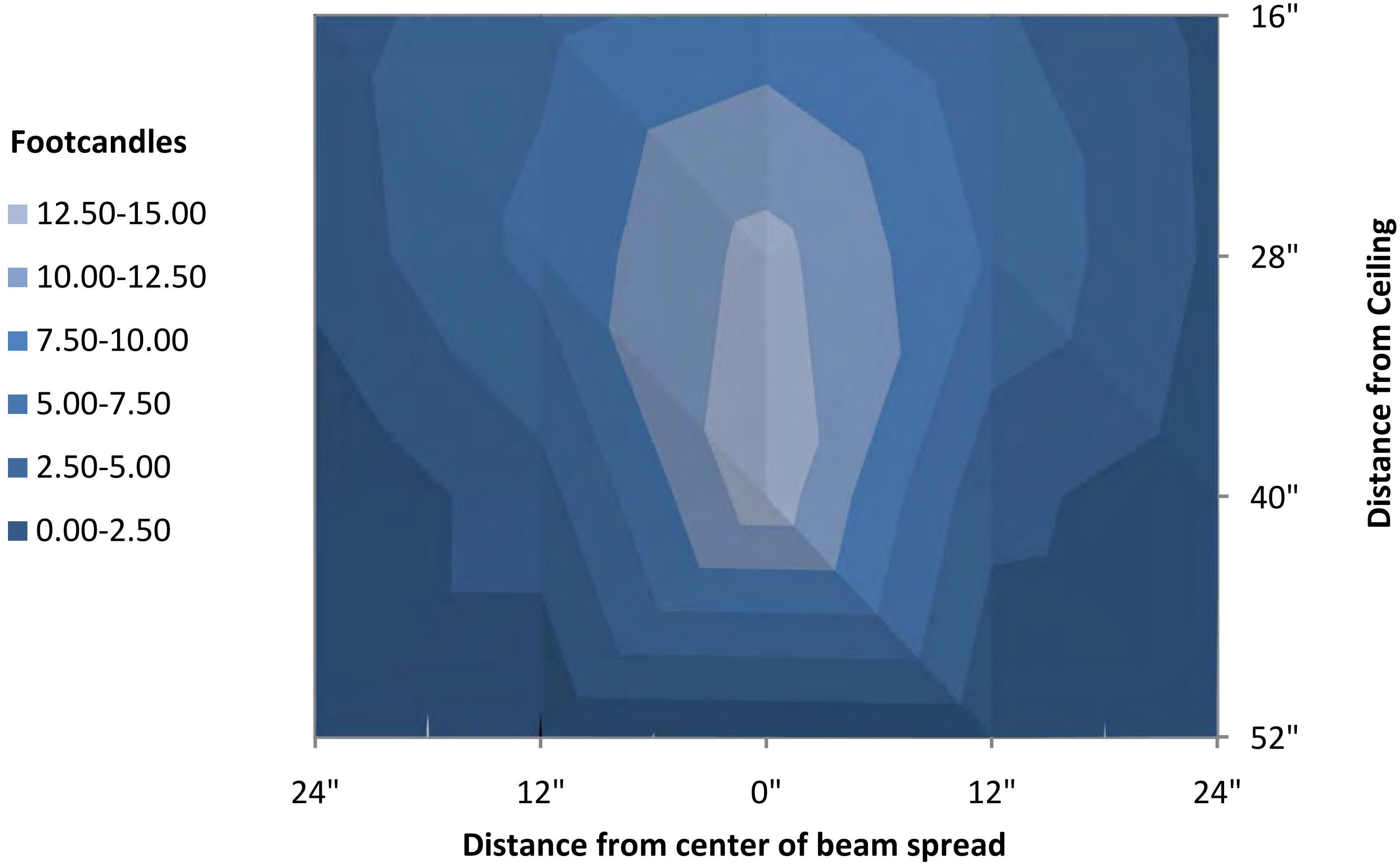
Base Case: Cove Illuminance

Test Case: Cove Illuminance

SPA LED Test Case (Wall) Illuminance



SPA MR 16 Base Case (Wall) Illuminance



Appendix C

Calculations

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Appendix C-1

System Efficacy

PG&E Emerging Technology Study: Retail LED Lighting **Hilton Hotel**

Comaprisons were drawn between published LM-79 compliant DOE CALiPER lab tests and the field data gathered from this study. Comparable lab test data was available for several applications as noted below. A direct and detailed comparison between the illuminance values gathered from a set of points in the field and the total lumens as measuerd in a testing sphere is not warranted. As imprecise as are the relative findings, the field results generally support the labopratory results in terms of the expecterd ratios of power to "light": LED sources fall between halogen and fluorescent sources in terms of overall efficacy.

DOE CALiPER Laboratory Testing Summary

DOE CALiPer efficacy values provided on the basis of lumens per watt

MR16								
Base Efficacy (i)	**Test Efficacy (ii)**	**∆ Efficacy (%)**	**Base Initial Lumens**	**Test Initial Lumens**	**∆ Intial Lumens (%)**	**Base Power**	**Test Power**	**∆ Power (%)**
12.7	24.9	96%	255	91	-64%	19.8	3.9	-80%

T8								
Base Efficacy (iii)	**Test Efficacy (iv)**	**∆ Efficacy (%)**	**Base Initial Lumens**	**Test Initial Lumens**	**∆ Intial Lumens (%)**	**Base Power**	**Test Power**	**∆ Power (%)**
96.0	39.0	-59%	3081	817	-73%	32.0	20.5	-36%

40W A-lamp & LED replacement								
Base Efficacy (v)	**Test Efficacy (vi)**	**∆ Efficacy (%)**	**Base Initial Lumens**	**Test Initial Lumens**	**∆ Intial Lumens (%)**	**Base Power**	**Test Power**	**∆ Power (%)**
10.2	33.3	226%	405	176	-57%	32.0	20.5	-36%

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PG&E Emerging Technology Study: Retail LED Lighting **Hilton Hotel**

Hilton Testing Summary (vii)

Test measurements for efficacy were not available for the installed product. The average illuminance values from selected field tests are provided below. Verified illuminance values were not available from the chandelier test.

Spa (MR16 Base, LED Test)						
Base Average Illuminance (fc)	**Test Average Illuminance (fc)**	**∆ Illuminance (%)**	**Unit Base Power (W)**	**Unit Test Power (W)**	**∆ Power (%)**	**Notes**
4.2	2.6	-38%	0.021	0.008	-62%	Conforms with expected results based on CALiPER tests, which is a greater reduction in power as compared to light

Cove (T8 Base, LED Test)						
Base Average Illuminance (fc)	**Test Average Illuminance (fc)**	**∆ Illuminance (%)**	**Unit Base Power (W)**	**Unit Test Power (W)**	**∆ Power (%)**	**Notes**
3.3	1.3	-61%	23.2	10.2	-56%	Conforms with expected results based on CALiPER, which is a greater reduction in light as compared to power.

Notes:

(i) Base case values are derived from CALiPER testing on six 20W Halogen MR-16 lamps. (CALiPER round 6 - Table 1c)
(ii) Test case values are derived from CALiPER testing on ten SSL MR-16 lamps (CALiPER round 6 - Table 2)
(iii) Base case values are derived from CALiPER testing on a 32W, 4ft. linear fluorescent lamp (CALiPER round 5 - Table 1b.)
(iv) Test case values are derived from CALiPER bare lamp testing on four 4ft. SSL linear replacement lamps (CALiPER round 5 - Table 1b.)
(v) Base case values are derived from CALiPER testing on 40W A lamps. (CALiPER Benchmark Report November 2008 Tables 1 and 2)
(vi) Test case values are derived from CALiPER testing on (10) replacement LED A-lamps. (CALiPER Benchmark Report November 2008 Table 3)
(vii) Base and test case values are derived from photometric and power measurements on the project site.

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PG&E Emerging Technology Study: Hotel LED Lighting **Hilton (San Francisco)**

Cove **(Vertical - Wall: Top to Bottom)**

Illuminance measurements were performed on the vertical wall paneling located between Elevators 4 and 5 in the Spa area. The height from floor to cove is 100", and the door panel area is 64" wide. For both base and test case, twelve measurements were performed on a 4x3 grid, taken nominally at eye level to correspond with the visual task of illuminating the elevator area while "washing" the wall paneling. The 0" position indicates placement at the left edge of the panel at the elevator door, facing the elevator; other measurements are towards the right at measurement heights above the floor as indicated in the table below. Measurements were performed on the vertical surface with the illuminance meter perpendicular to the horizon. Other contributing general and accent lighting systems were switched off while the measurements were performed.

Illuminance Results (fc)

	Fluorescent Base Case					**LED Test Case**			
Height above floor	0" Left	16" Center	32" Right		Height above floor	0" Left	16" Center	32" Right	
84"	6.58	6.15	6.17		84"	3.02	2.88	3.00	
72"	3.34	3.22	3.20		72"	1.29	1.31	1.33	
60"	2.07	2.10	2.08		60"	0.65	0.67	0.77	
48"	1.50	1.53	1.53		48"	0.36	0.39	0.33	
	Minimum		1.5			Minimum		0.3	
	Average		3.3			Average		1.3	-60.6%
	Maximum		6.6			Maximum		3.0	
	Max:Min		2.0	:1		Max:Min		2.3	:1
	Avg:Min		0.5	:1		Avg:Min		0.2	:1

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Spa MR16 **(Vertical - Wall: Top to Bottom)**

Illuminance measurements were performed on the vertical wall in the Spa seating area within the spread pattern of a single fixture. Base and test case lighting measurements were taken in separate but similar areas. For both base and test case, twenty measurements were performed on a 4x5 grid, taken just above the furniture to correspond with the visual task of illuminating the artwork while "washing" the wall surface. The top position (extent of the beam spread) indicates placement 16” below the ceiling, with positions every 12” from left to right and top to bottom. Measurement heights below the ceiling are indicated in the table below. Measurements were performed on the vertical surface with the illuminance meter perpendicular to the horizon. Other contributing general and accent lighting systems were switched off while the measurements were performed.

Illuminance Results (fc)

	Halogen Base Case						LED Test Case					
Distance from ceiling	12"	24"	36"	48"	60"			12"	24"	36"	48"	60"
16"	0.16	0.19	0.42	0.63	0.15			0.07	0.30	0.53	0.25	0.25
28"	0.12	4.03	14.12	3.25	0.84			0.26	0.80	5.78	1.81	0.66
40"	3.36	8.22	13.43	7.21	2.01			0.19	1.92	10.51	7.57	1.58
52"	3.90	6.89	8.63	5.40	1.78			0.33	3.18	8.48	5.07	3.38
	Minimum		0.1					Minimum		0.1		
	Average		4.2					Average		2.6	-38.1%	
	Maximum		14.1					Maximum		10.5		
	Max:Min		3.4	:1				Max:Min		4.0	:1	
	Avg:Min		0.0	:1				Avg:Min		0.0	:1	

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Downlights (Vertical - Wall)

The lighting task is taken to be the wall of the hallway, at eye level, so as to illuminate the surrounding pathway and decor.
Positions are 1-5, on the wall space of the hallway. The pattern is an "X" shape with the top row 6 feet high, the middle row 51 inches high and the bottom row 30 inches high.

Illuminance Results (fc)

	Position	CFL	LED	Avg. CFL	Avg. LED
Downlights (Vertical - Wall)	1st	2.9	0.4	3.1	0.9
	2nd	3.1	0.4	3.1	0.9
	3rd	3.2	1.1	3.1	0.9
	4th	3.0	1.2	3.1	0.9
	5th	3.4	1.2	3.1	0.9
	Max:	3.4	1.2	3.1	0.9
	Min:	2.9	0.4		
	Average:	**3.1**	**0.9**		

Δ Average (%) -71%

PG&E Emerging Technology Study: Retail LED Lighting
Hilton Hotel

Chandeliers **(Surfaces)**

Luminance measurements were conducted on the surface of the chandelier crystal surfaces. The lighting task was judged to be visual interest in the fixture itself, best gauged by the amount of available reflected light. Positions are 1-5, on the chandelier crystals. The pattern is an "X" shape at the four corners and in the center of the chandelier.

Luminance results (cd/m2)

	Position	Incand	LED	Avg. Incand	Avg. LED
Chandelier (Crystal Surfaces)	1st	81.9	215.4	81.9	223.2
	2nd	61.9	223.4	81.9	223.2
	3rd	109.5	238.6	81.9	223.2
	4th	71.8	208.3	81.9	223.2
	5th	84.7	230.4	81.9	223.2
	Max:	109.5	238.6		
	Min:	61.9	208.3		
	Average:	**81.9**	**223.2**		

Δ Average (%) 173%

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PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco)

Positions are 1-5, measured from left to right on the wall at 6' 6" above the floor, every 8' along the length of the cove lighting.

Color Temperature (CCT) results (degree K)

	Position	Fluorescent	LED	Avg. Fl.	Avg. LED
Cove (Vertical - Across Wall, High)	1st	2495	2524	2512	2507
	2nd	2556	2528	2512	2507
	3rd	2534	2508	2512	2507
	4th	2488	2489	2512	2507
	5th	2485	2486	2512	2507
	Max:	2556	2528	2512	2507
	Min:	2485	2486		
	Average:	**2512**	**2507**		
			∆ Average (%)	0%	

Positions are 1-5, on the wall space between two elevator doors. The pattern is an "X" shape with the top row 6 feet high, the middle row 51 inches high and the bottom row 30 inches high.

Color Temperature (CCT) results (degree K)

	Position	Fluorescent	LED	Avg. Fl.	Avg. LED
Cove (Vertical - Wall: Top to Bottom)	1st	2657	2554	2523	2511
	2nd	2539	2587	2523	2511
	3rd	2453	2499	2523	2511
	4th	2494	2477	2523	2511
	5th	2470	2438	2523	2511
	Max:	2657	2587	2523	2511
	Min:	2453	2438		
	Average:	**2523**	**2511**		
			∆ Average (%)	0%	

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Positions are 1-5, on the wall space washed by the MR16s. The pattern is an "X" shape with the top row 6 feet high, the middle row 51 inches high and the bottom row 30 inches high.

Color Temperature (CCT) results (degree K)					
	Position	**Halogen**	**LED**	**Avg. Halogen**	**Avg. LED**
MR16 (Vertical - Wall: Top to Bottom)	1st	2825	2933	2778	2869
	2nd	2646	2865	2778	2869
	3rd	2986	2833	2778	2869
	4th	2565	2855	2778	2869
	5th	2870	2861	2778	2869
	Max:	2986	2933	2778	2869
	Min:	2565	2833		
	Average:	**2778**	**2869**		
			∆ Average (%)	3%	

Positions are 1-5, below the chandelier at a height of 30 inches. The pattern is an "X" shape at the four corners and in the center of the chandelier.

Color Temperature (CCT) results (degree K)					
	Position	**Incand**	**LED**	**Avg. Incand**	**Avg. LED**
Chandelier (Horizontal, 30"above Floor)	1st	2425	3222	2432	3255
	2nd	2433	3256	2432	3255
	3rd	2428	3337	2432	3255
	4th	2441	3240	2432	3255
	5th	2432	3222	2432	3255
	Max:	2441	3337	2432	3255
	Min:	2425	3222		
	Average:	**2432**	**3255**		
			∆ Average (%)	34%	

Phone: 415.434.2600

Positions are 1-5, on the wall space of the hallway. The pattern is an "X" shape with the top row 6 feet high, the middle row 51 inches high and the bottom row 30 inches high.

Color Temperature (CCT) results (degree K)

	Position	CFL	LED	Avg. CFL	Avg. LED
Downlights (Vertical - Wall)	1st	2585	3051	2556	3109
	2nd	2583	2962	2556	3109
	3rd	2562	3400	2556	3109
	4th	2522	3049	2556	3109
	5th	2527	3082	2556	3109
	Max:	2585	3400	2556	3109
	Min:	2522	2962		
	Average:	**2556**	**3109**		
			∆ Average (%)	22%	

Positions are 1-5, below the lamp at a height of 30 inches. The pattern is an "X" shape at the below the lamp

Color Temperature (CCT) results (degree K)

	Position	CFL	LED	Avg. CFL	Avg. LED
Downlights (Horizontal 30" above Floor)	1st	2333	-	2385	2702
	2nd	2346	-	2385	2702
	3rd	2542	2802	2385	2702
	4th	2360	2635	2385	2702
	5th	2346	2668	2385	2702
	Max:	2542	2802	2385	2702
	Min:	2333	2635		
	Average:	**2385**	**2702**		
			∆ Average (%)	13%	

Phone: 415.434.2600

Appendix C-2

Project Savings and Economics

PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco) Energy Savings

The calculated savings is based on 4 separate lighting replacement projects as described in detail below and summarized.

Spa Cove Lighting Retrofit Energy Savings

This project replaced (7) 4’ T8 fluorescent lamps and (3) 3' T8 lamps (and associated ballasts) with (9) 4’ LED light bars and one driver in the cove lighting above the elevators in the hotel spa. The “average measured power” data is determined from two switched legs controlled by a single switch and measured independently: In one position, the base case cove lighting of (10) single fluorescent lamps was energized and power was recorded for approximately 30 minutes. The switch position was changed to energize the LED lighting load consisting of 9 light bars, for which power was recorded for 30 minutes. Operating hours for the Spa area are (18 hours/day * 365 days/year) = 6,570 hours/year. This operating schedule was provided by facility operations. Data was also collected from the entire lighting circuit, which includes other loads. The data collected from the entire circuit indicate an annualized use of 8,165 hours per year (> 22 hours per day) of lighting use on average, which is reasonable for the cove lighting as the additional usage outside of scheduled operation is due to lights being engaged by night security during inspection rounds.

	Annual Operating Hours (hrs/yr)	Average Measured Power (kW)	Existing Fixture Quantity	LED Fixture Quantity	Watts/ Fixture *	Calculated Energy (kWh/yr)	% reduction in kWh
T8 Fluorescent	8,165	0.232	10	-	23.2	1,894	
LED Light Bar	8,165	0.092	-	9	10.2	751	
Savings		0.140				1,143	60%

Calculated Savings/Fixture: 0.014 kW

Electric Demand Savings: 0.140 kW
Electric Energy Savings: 1,143 kWh/yr

* Watts per fluorescent fixture is composite value for 3' and 4' lamps.

* Unit power per light bar constrained by rated power of driver, nominally 100W for entire cove at 0.9 PF.

Spa MR16 Retrofit Energy Savings

This project replaced (9) 20-Watt halogen MR16 lamps with (9) LED MR16 lamps, which are used as overhead task lighting in the waiting area of the spa. The circuit that serves these lamps could not be properly isolated, so the lamps were bench tested and data was recorded for 1 hour. The “Average Measured kW/fixture” data is determined from the monitored data. The “Calculated Demand” and “Calculated Energy” data is extrapolated from the monitored data to account for the project fixtures. Operating hours for these lamps are (18 hours/day * 365 days/year) = 6,570 hours/year. This operating schedule was provided by facility operations; night security does not regularly engage these fixtures outside of normal operating hours.

	Annual Operating Hours (hrs/yr)	Average Measured kW/fixture	Existing Fixture Quantity	LED Fixture Quantity	Calculated Demand (kW) *	Calculated Energy (kWh/yr)	% reduction in kWh
20 W Hal. MR16	6,570	0.021	9	-	0.189	1,242	
LED MR16	6,570	0.008	-	9	0.072	473	
Savings		0.013			0.117	769	62%

Electric Demand Savings: 0.117 kW
Electric Energy Savings: 769 kWh/yr

* for the (9) lamps replaced.

Chandelier Retrofit Energy Savings

This project replaced (37) 40-Watt incandescent screw-in lamps with (37) screw-in LED lamps in a hallway chandelier in the hotel. There are (3) of these chandeliers in the hotel, each chandelier contains (37) 40-Watt incandescent lamps for a total of (111) lamps. The circuit that serves these lamps could not be properly isolated, so the lamps were bench tested and data was recorded for 1 hour. The “Average Measured kW/fixture” data is determined from the monitored data. The “Calculated Demand” and “Calculated Energy” data is extrapolated from the monitored data to calculate the savings available from replacing the (37) 40-Watt incandescent lamps (1 chandelier). Operating hours for these lamps were (24 hours/day * 365 days/year) = 8,760 hours/year. This operating schedule was provided by facility operations.

	Annual Operating Hours (hrs/yr)	Average Measured (kW/fixt.)	Existing Fixture Quantity	LED Fixture Quantity	Calculated Demand (kW) *	Calculated Energy (kWh/yr) *	% reduction in kWh
40 W Incand.	8,760	0.037	37	-	1.369	11,992	
LED Lamp	8,760	0.002	-	37	0.074	648	
Savings		0.035			1.295	11,344	95%

Electric Demand Savings: 1.295 kW
Electric Energy Savings: 11,344 kWh/yr

* for the (37) lamps replaced.

Hallway Downlight Retrofit Energy Savings

This project replaced (20) 30-Watt compact flourescent screw-in lamps with (20) screw-in LED PAR30 lamps in a hallway in the hotel. The circuit that serves these lamps could not be properly isolated, so the lamps were bench tested and data was recorded for 1 hour. The “Average Measured kW/fixture” data is determined from the monitored data. The “Calculated Demand” and “Calculated Energy” data is extrapolated from the monitored data to calculate the savings available from replacing the (20) 30-Watt compact flourescent lamps. Operating hours for these lamps were (24 hours/day * 365 days/year) 8,760 hours/year. This operating schedule was provided by facility operations.

	Annual Operating Hours (hrs/yr)	Average Measured (kW/fixt.)	Existing Fixture Quantity	LED Fixture Quantity	Calculated Demand (kW) *	Calculated Energy (kWh/yr) *	% reduction in kWh
30 W CFL	8,760	0.024	20	-	0.480	4,205	
LED PAR30	8,760	0.013	-	20	0.260	2,278	
Savings		0.011			0.220	1,927	46%

Electric Demand Savings: 0.220 kW
Electric Energy Savings: 1,927 kWh/yr

* for the (20) lamps replaced.

Energy Savings Summary, Total for (4) Demonstation Projects

Total Base Case Demand	**2.270**	**kW**	
Total Test Case Demand	**0.498**	**kW**	
Total Demand Savings:	**1.772**	**kW**	
Total Energy Savings:	**15,183**	**kWh/yr**	
Energy Rate:	**$ 0.10310**	**/kWh**	*(per rate calculation for continuous use, schedule E-20S)*
Annual Dollar Savings, Energy:	**$ 1,565.37**	**/yr.**	
Annual Avoided Maint. Cost:	**$ 1,743.58**	**/yr.**	*(per avoided cost calculation)*
Total Annual Savings:	**$ 3,308.95**	**/yr.**	

overall % reduction in load	**78.1%**	
overall % reduction, energy use	**78.1%**	*(equivalent percentage to reduction in load; operating hours held constant)*

Recap of Cost and Payback, Total for (4) Demonstration Projects

Project Cost	**$ 4,256.45**	
Payback, Energy	**2.7**	**yrs**
Payback, Energy & Maintenance	**1.3**	**yrs**

PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco) Cost Summary and Payback

The economic analysis shown below indicates the anticipated cost and savings for current market conditions. The "payback period with avoided cost" scenarios include additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

SPA COVE LIGHTING PROJECT:

	LED Bars:	Notes:
Quantity:	9	
$/4' Bar	$ 152.00	
Material Cost:	$ 1,368.00	
	Labor:	
Quantity	9	
Cost/bar	$ 18.91	As observed at similar installation.
Labor Cost:	$ 170.19	
	Total:	
Total Cost:	$1,538.19	

Spa Cove Lighting Project Payback Summary	
Annual Energy Savings $ 117.84 /yr	**Simple Payback Period, Current Market** **13.1 years**
Total Annual Savings $ 338.04 /yr	**Payback Period w/Avoided Cost, Current Market** **4.6 years**

Cost Details

	$ 152.00	Source LEDPower, for 36 LED/foot ($34/foot in high volume), plus 20% of a driver, Cary Aberg, 6/25/08.

SIMPLE PAYBACK VS. RATED LIFE: Entrance Cove Lighting

Useful Life:	50,000	hrs
Operation	8,165	hrs/yr
Expected Life	6.1	yrs, based on annual operation over useful life.
Project Payback	13.1	yrs (based on energy alone, current market conditions)

PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco) Cost Summary and Payback

The economic analysis shown below indicates the anticipated cost and savings for current market conditions. The "payback period with avoided cost" scenarios include additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

SPA MR16 PROJECT:

	LED MR16:	Notes:
Quantity:	9	
Lamp	$ 35.00	
Material Cost:	$ 315.00	
	Labor:	
Quantity	9	
Cost/unit	$ 5.11	Uses Means labor hours to replace lamp.
Labor Cost:	$ 45.99	
	Total:	
Total Cost:	$360.99	

Spa MR16 Project Payback Summary	
Annual Energy Savings $ 79.28 /yr	**Simple Payback Period, Current Market** **4.6 years**
Total Annual Savings $ 442.79 /yr	**Payback Period w/Avoided Cost, Current Market** **0.8 years**

Cost Details

	$ 35.00	Bud Grandsaert, Vice President of Sales and Marketing at Illumination Management Systems 1/7/09

SIMPLE PAYBACK VS. RATED LIFE: MR 16 Spa

Useful Life:	50,000	hrs
Operation	6,570	hrs/yr
Expected Life	7.6	yrs, based on annual operation over useful life.
Project Payback	4.6	yrs (based on energy alone, current market conditions)

PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco) Cost Summary and Payback

The economic analysis shown below indicates the anticipated cost and savings for current market conditions. The "payback period with avoided cost" scenarios include additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

CHANDELIER PROJECT:

	LED Lamp	Notes:
Quantity:	37	
Lamp	$ 18.00	
Material Cost:	$ 666.00	
	Labor:	
Quantity	37	
Cost/lamp	$ 5.11	Uses Means labor hours to replace lamp.
Labor Cost:	$ 189.07	
	Total:	
Total Cost:	$855.07	

Chandelier Project Payback Summary	
Annual Energy Savings $ 1,169.57 /yr	**Simple Payback Period, Current Market** **0.7 years**
Total Annual Savings $ 2,039.44 /yr	**Payback Period w/Avoided Cost, Current Market** **0.4 year**

Cost Details

$ 18.00 Source LEDPower, Cary Aberg, 6/25/08.

SIMPLE PAYBACK VS. RATED LIFE: Chandelier Project

Useful Life:	50,000	hrs
Operation	8,760	hrs/yr
Expected Life	5.7	yrs, based on annual operation over useful life.
Project Payback	0.7	yrs (based on energy alone, current market conditions)

PG&E Emerging Technology Study: Hotel LED Lighting
Hilton (San Francisco) **Cost Summary and Payback**

The economic analysis shown below indicates the anticipated cost and savings for current market conditions. The "payback period with avoided cost" scenarios include additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

HALLWAY DOWNLIGHT PROJECT:

	LED Lamp	Notes:
Quantity:	20	
Lamp	$ 70.00	
Material Cost:	$ 1,400.00	
	Labor:	
Quantity	20	
Cost/lamp	$ 5.11	Uses Means labor hours to replace lamp.
Labor Cost:	$ 102.20	
	Total:	
Total Cost:	$1,502.20	

Hallway Downlight Project Payback Summary	
Annual Energy Savings $ 198.67 /yr	**Simple Payback Period, Current Market** **7.6 years**
Total Annual Savings $ 488.67 /yr	**Payback Period w/Avoided Cost, Current Market** **3.1 year**

Cost Details

$ 70.00 Source LEDPower, Cary Aberg, 6/25/08.

SIMPLE PAYBACK VS. RATED LIFE: Hallway Downlight

Useful Life:	50,000	hrs
Operation	8,760	hrs/yr
Expected Life	5.7	yrs, based on annual operation over useful life.
Project Payback	7.6	yrs (based on energy alone, current market conditions)

INITIAL MAINTENANCE SAVINGS FOR REPLACEMENT OF FLUORESCENT SOURCES WITH LED SOURCES

Replacement of existing lighting systems with new LED systems will typically result in avoided maintenance costs over the life of the new LED system because of the longer rated life of LED systems compared to existing lighting systems. Based on average life characteristics of the current and proposed equipment, more than 2 cycles of existing lamp replacement will be avoided during the expected life of the LED system. During that period, it is predicted that a small percentage of fluorescent ballasts will fail based on the calculated annual failure rate; actual failures will likely be higher or lower depending on the age of the existing ballasts. The overall avoided maintenance costs during the expected life of the LED system are calculated below:

Equipment	Type	Expected Life (hrs) (1)	Annual Failure Rate (2)	Unit Labor Hrs (3)	Unit Labor Cost (4)	Unit Material Cost (5)	Unit Replacement cost	Total Unit Replacements in LED life	Unit Replacement Cost per LED life cycle				Annualized Cost	Quantity of Existing Units	Total Net Annualized Savings
									Cove	MR16	Chand	PAR30			
GE F32T8-SP30-ECO	lamp	20,000	43.8%	0.089	$ 9.10	$ 2.53	$ 11.63	2.50	$ 29.08						
Sylvania QTP4x32T8	ballast	60,000	14.6%	0.851	$ 86.97	$ 29.41	$ 116.38	0.83	$ 96.60						
Sylvania 40 W A19	lamp	3,000	292.0%	0.050	$ 5.11	$ 2.94	$ 8.05	16.67			$ 134.19				
Sylvania 20W MR16	lamp	3,000	292.0%	0.062	$ 6.34	$ 7.49	$ 13.83	16.67		$ 230.55					
Sylvania 30W CFL	lamp	10,000	87.6%	0.050	$ 5.11	$ 11.44	$ 16.55	5.00				$ 82.75			
LED light bar (4') for cove	unit	50,000	17.5%	0.185	$ 18.91	$ 152.00	$ 170.91	-	$ 170.91						
LED Lamp	unit	50,000	17.5%	0.050	$ 5.11	$ 18.00	$ 23.11	-			$ 23.11				
LED MR16	unit	50,000	17.5%	0.062	$ 6.34	$ 35.00	$ 41.34	-		$ 41.34					
LED PAR30	unit	50,000	17.5%	0.050	$ 5.11	$ 70.00	$ 75.11	-				$ 75.11			
TOTALS:								**Cove:**	**$ 125.67**				**$ 22.02**	**10**	**$ 220.20**
								MR16:		**$ 230.55**			**$ 40.39**	**9**	**$ 363.51**
								Chandelier:			**$ 134.19**		**$ 23.51**	**37**	**$ 869.87**
								PAR30				**$ 82.75**	**$ 14.50**	**20**	**$ 290.00**

(1) Assume Rated lamp life at 3 Hrs/Start per industry standard rating; ballast and LED system life of 50,000 hours per manufacturer.
(2) Annual failure rate = Annual operating hours / expected life. Assume operating hours to be: 8,760 /yr as calculated for this case study. **Total: $ 1,743.58**
(3) Labor hours per 2007 Means for lighting maintenance activities (spot relamp/reballast); labor hours for LED as follows:

26 61 23.10 0180 - 4' T8 - 32 Watt Energy Saver:	0.089	Labor Hours
26 51 13.50 7540 - Ballast Replacement:	0.851	Labor Hours
26 61 23.10 1800 - Incandescent Lamp, Interior, A21:	0.050	Labor Hours
26 61 23.10 1762 - 50 Watt, Spot, MR16:	0.062	Labor Hours
LED light bar (4') for cove:	0.185	Labor Hours, as observed at similar installation.

(4) Assume Labor Rate at $ 102.20 /hr. (Means Electrical 2007 for Electrician; City modifier San Francisco, CA.)
(5) Materials cost for existing systems per www.grainger.com and sylvanialighting.com, 10/06/08. LED systems per LEDPower, Cary Aberg, 6/25/08.

Project: ELECTRICITY RATE ANALYSIS - DEFINITIONS
Customer: PG&E
Facility: Hilton
Building: San Francisco

Utility: PG&E
Rate Schedule E-20S
Effective Date: January 1, 2008
Revised: Cal. P.U.C. Sheet No. 26954-E

Background

This sheet summarizes the energy and demand charges during summer and winter for peak, partial-peak, and off-peak periods for time-of-use rate schedules.

Approach

The user enters the appropriate utility period definitions and rates on this sheet. Average electric rates are calculated for various use profiles on the following sheets.

Assumptions

Holidays as defined in this rate schedule are assigned to the legally observed dates. When a billing month includes both summer and winter days, demand charges are calculated by prorating separately calculated winter and summer demand charges by the appropriate number of days in each season during the billing period. This spreadsheet does not calculate this proration; billing periods are assumed to coincide with season changeover dates. This spreadsheet does not include customer charges or state and local taxes. The calculations assume peak and maximum demand are concurrent.

Analysis

UTILITY PERIOD DEFINITIONS

SUMMER May 1-October 31 6 months

PERIOD DEFINITIONS						BREAKDOWN			SUMMARY BY PERIOD		
period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
peak	1200	to	1800	5	M/F	6	26.07	782	782		
partial-peak	830	to	1200	5	M/F	3.5	26.07	456		456	
	1800	to	2130	5	M/F	3.5	26.07	456		456	
off-peak	2130	to	830	5	M/F	11	26.07	1,434			1,434
	-	to	2400	2	S/S	24	26.07	1,251			1,251
Weekday holidays which are completely off-peak:						(	3)		(18)	(21)	39

WINTER Nov 1-April 30 6 months

PERIOD DEFINITIONS						BREAKDOWN					
period	daily hours			days per week		hr/day	wk/yr	hr/yr			
peak	-	to	-	5	M/F	0	26.07	0	0		
partial-peak	830	to	2130	5	M/F	13	26.07	1,695		1,695	
	-	to	-	5	M/F	0	26.07	0		0	
off-peak	2130	to	830	5	M/F	11	26.07	1,434			1,434
	-	to	2400	2	S/S	24	26.07	1,251			1,251
Weekday holidays which are completely off-peak:						(	5)		0	(65)	65
								TOTAL ==>	764	2,521	5,474
								% total	8.7%	28.8%	62.5%

UTILITY RATE STRUCTURE (Non-FTA)

		ENERGY	DEMAND	
		$/kWh	$/kW peak	$/kW max
SUMMER:	May 1-October 31			
	peak	0.13593	12.40	7.52
	partial-peak	0.09204	2.74	
	off-peak	0.07392	0.00	
WINTER:	Nov 1-April 30			
	peak	0.00000	0.00	
	partial-peak	0.08155	1.04	7.52
	off-peak	0.07118	0.00	

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Project:	ELECTRICITY RATE ANALYSIS - PROJECT RATE	**Utility:**	PG&E
Customer:	PG&E	**Rate Schedule**	E-20S
Facility:	Hilton	**Effective Date:**	January 1, 2008
Building:	San Francisco	**Revised:**	Cal. P.U.C. Sheet No. 26954-E

Background

This worksheet calculates the marginal cost of electricity with and without demand, for a particular operating use profile.

Approach

This sheet calculates the number of hours per year a given building operates during peak, partial-peak, and off-peak periods. It then uses the data from the TOU Utility Definitions tab to calculate the marginal cost of electricity.

Assumptions

Holidays as defined in this rate schedule are assigned to the legally observed dates. When a billing month includes both summer and winter days, demand charges are calculated by prorating separately calculated winter and summer demand charges by the appropriate number of days in each season during the billing period. This spreadsheet does not calculate this proration; billing periods are assumed to coincide with season changeover dates. This spreadsheet does not include customer charges or state and local taxes. The calculations assume peak and maximum demand are concurrent.

Analysis

TIME PERIOD: **Hotel lighting operating hours**

OCCURRENCE OF PROJECT SAVINGS: **24/7**

SUMMER May 1-October 31 6 months

SCHEDULE						SAVINGS SCHEDULE			SUMMARY BY PERIOD		
period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
peak	1200	to	1800	5	M/F	6.0	26.07	782	782		
partial-peak	830	to	1200	5	M/F	3.5	26.07	456		456	
	1800	to	2130	5	M/F	3.5	26.07	456		456	
off-peak	2130	to	830	5	M/F	11.0	26.07	1,434			1,434
	-	to	2400	2	S/S	24.0	26.07	1,251			1,251
Weekday holidays which are completely off-peak:						(	3)		(18)	(21)	39

WINTER Nov 1-April 30 6 months

SCHEDULE						SAVINGS SCHEDULE					
period	daily hours			days per week		hr/day	wk/yr	hr/yr			
peak	-	to	-	5	M/F	0.0	26.07	0	0.0		
partial-peak	830	to	2130	5	M/F	13.0	26.07	1,695		1,694.6	
	-	to	-	5	M/F	0.0	26.07	0		0.0	
off-peak	2130	to	830	5	M/F	11.0	26.07	1,434			1,433.9
	-	to	2400	2	S/S	24.0	26.07	1,251			1,251.4
						0.0					
Weekday holidays which are completely off-peak:						(	5)		0.0	(65.0)	65.0
								TOTAL ==>	764.1	2521.0	5474.6
								% total	8.7%	28.8%	62.5%

PROJECT UTILITY RATE:

Energy Savings: 1 additional kW saved x 8,760 hrs/yr = 8,760 kWh/yr

Demand Savings: 1 kW per month

	ENERGY	DEMAND	
SUMMER	$/kW	$/kW	$/kW
period		peak	max
peak	103.86	74.40	45.12
partial-peak	82.04	16.44	0.00
off-peak	201.38	0.00	0.00
subtotal	387.28	90.84	45.12
WINTER			
period			
peak	0.00	0.00	0.00
partial-peak	132.89	6.24	45.12
off-peak	195.77	0.00	0.00
subtotal	328.66	6.24	45.12

AVERAGE RATE CALCULATION

$715.94	/yr avoided energy charges
$97.08	/yr avoided time-related demand charges
$90.24	/yr avoided nontime-related demand charges
$903.26	/yr
$0.1031	/kWh average annual electric rate INCLUDING demand *
$0.0817	/kWh average annual elec rate NOT INCLUDING demand

* correct project rate for load reducing project includes demand

EMCOR Energy Services

Appendix D

Product Specifications

26666 – F32T8/SP30/ECO

GE Ecolux® Starcoat® T8

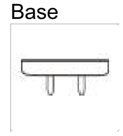
PRINT

• Passes TCLP, which can lower disposal costs.

High Color Rendering
Meets Federal Minimum Efficiency Standards

Bulb

Base



View Larger

GENERAL CHARACTERISTICS

Lamp type	Linear Fluorescent - Straight Linear
Bulb	T8
Base	Medium Bi-Pin (G13)
Wattage	32
Voltage	137
Rated Life	20000 hrs
Rated Life (instant start) @ Time	20000 h @ 3 h 24000 h @ 12 h
Rated Life (rapid start) @ Time	24000 h @ 12 h
Bulb Material	Soda lime
Starting Temperature (MIN)	10 °C (50 °F)
Additional Info	TCLP compliant

PHOTOMETRIC CHARACTERISTICS

Initial Lumens	2800
Mean Lumens	2660
Nominal Initial Lumens per Watt	87
Color Temperature	3000 K
Color Rendering Index (CRI)	78
S/P Ratio (Scotopic/Photopic Ratio)	1.3

ELECTRICAL CHARACTERISTICS

Open Circuit Voltage (rapid start) Min @ Temperature	315 V @ 10 °C
Cathode Resistance Ratio - Rh/Rc (MIN)	4.25
Cathode Resistance Ratio - Rh/Rc (MAX)	6.5
Current Crest Factor (MAX)	1.7

DIMENSIONS

Maximum Overall Length (MOL)	47.7800 in (1213.6 mm)
Minimum Overall Length	47.6700 in (1210.8 mm)
Nominal Length	48.000 in (1219.2 mm)

ADDITIONAL RESOURCES

Catalogs
Testimonials
Brochures
Product Brochures
- Color
- Ecolux
- Ecolux (Environmental)
- Industrial Lighting
- Linear Fluorescent Lamps

Application/Segment Brochures
- Contractor Lighting
- Healthcare Lighting
- Office Lighting
- Retail Lighting

MSDS (Material Safety Data Sheets)
Disposal Policies & Recycling Information

GRAPHS & CHARTS

Spectral Power Distribution

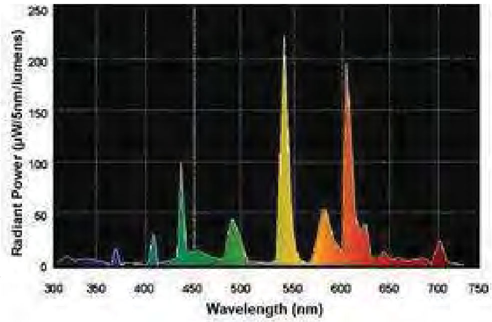
Bulb Diameter (DIA)	1.000 in (25.4 mm)
Bulb Diameter (DIA) (MIN)	0.940 in (23.8 mm)
Bulb Diameter (DIA) (MAX)	1.100 in (27.9 mm)
Max Base Face to Base Face (A)	47.220 in (1199.3 mm)
Face to End of Opposing Pin (B) (MIN)	47.400 in (1203.9 mm)
Face to End of Opposing Pin (B) (MAX)	47.500 in (1206.5 mm)
End of Base Pin to End of Opposite Pin End (C)	47.670 in (1210.8 mm)

PRODUCT INFORMATION

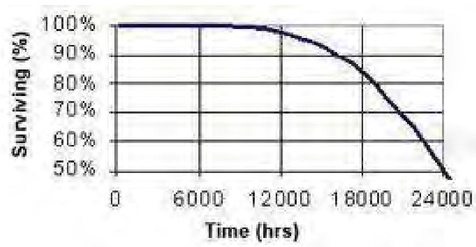
Product Code	26666
Description	F32T8/SP30/ECO
ANSI Code	1005-2
Standard Package	Case
Standard Package GTIN	10043168266663
Standard Package Quantity	36
Sales Unit	Unit
No Of Items Per Sales Unit	1
No Of Items Per Standard Package	36
UPC	043168266666

COMPATIBLE GE BALLASTS

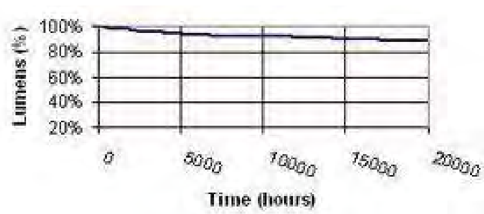
Product Code	Description	# of Bulbs	Power Factor	Ballast Factor
80353	B132R120V5	1	90.0	0.88
80355	B232SR120V5	2	90.0	0.88
80362	B232SR277S50	2	90.0	0.88
80356	B232SR277V5	2		0.88
80357	B332SR120V5	3	90.0	0.88
80358	B332SR277V5	3	90.0	0.88
23680	GE-132-120-N	1	99.0	0.87
24161	GE-132-120-N-84T	1	99.0	0.87
23681	GE-132-277-N	1	99.0	0.87
24162	GE-132-277-N-84T	1	99.0	0.87
72258	GE132MAX-L/ULTRA	1	99.0	0.77
49706	GE132MAX-L/ULTRA	1	99.0	0.77
72260	GE132MAX-N-DIY	1	99.0	0.87
49771	GE132MAX-N/ULTRA	1	99.0	0.88
72259	GE132MAX-N/ULTRA	1	99.0	0.87
72269	GE-132-MV-N	1	99.0	0.87
30189	GE-132-MV-N	1	99.0	0.87
30268	GE-132-MV-N-42T	1	99.0	0.87
72270	GE-132-MV-N-42T	1	99.0	0.87
23671	GE-232-120-N	1	99.0	0.94
24163	GE-232-120-N-84T	1	99.0	0.94
29621	GE-232-120-PS-N	1	99.0	1.03
29630	GE-232-120PS-N-T	1	99.0	1.03
97782	GE232-120-RES	1	48.0	0.99



Lamp Mortality



Lumen Maintenance



YOU MIGHT ALSO BE INTERESTED IN...

For Energy

GE Ecolux® Watt-Miser® Starcoat® T8
Product code: 48277

• Passes TCLP, which can lower disposal costs.

• Saves energy compared to standard wattage lamps

COMPARE

GE Ecolux® Starcoat® T8
Product code: 72128

• Saves energy compared to standard wattage lamps

• Passes TCLP, which can lower disposal costs.

COMPARE

For Better Light

GE Ecolux® Starcoat® T8
Product code: 27619

• Passes TCLP, which can lower disposal costs.

• Provides significantly longer life than standard lamp helping to reduce maintenance costs

COMPARE

71037	GE232-120RES-DIY	1	48.0	0.99
23672	GE-232-277-N	2	99.0	0.94
24164	GE-232-277-N-84T	2	99.0	0.94
29622	GE-232-277-PS-N	1	95.0	1.03
29632	GE-232-277PS-N-T	1	95.0	1.03
47548	GE232MAX-H-42T	1	99.0	1.15
49775	GE232MAX-H/ULTRA	1	99.0	1.15
72263	GE232MAX-L-42T	1	99.0	0.77
49707	GE232MAX-L/ULTRA	1	99.0	0.77
72262	GE232MAX-L/ULTRA	1	99.0	0.77
71421	GE232MAX-N+	1	99.0	1.0
31052	GE232MAX-N-42T	1	99.0	0.87
72267	GE232MAX-N-42T	1	99.0	0.87
72264	GE232MAX-N/AMP	1	99.0	0.87
97656	GE232MAX-N/CTR	1	99.0	0.87
72265	GE232MAX-N/CTR	1	99.0	0.87
72268	GE232MAX-N-DIY	1	99.0	0.87
23940	GE232MAX-N-DIY	1	99.0	0.87
49772	GE232MAX-N/ULTRA	1	99.0	0.87
72266	GE232MAX-N/ULTRA	1	99.0	0.87
30198	GE-232-MV-H	1	99.0	1.34
30275	GE-232-MV-H-42T	1	99.0	1.34
72273	GE-232-MV-L	1	99.0	0.93
30247	GE-232-MV-L	1	99.0	0.93
72274	GE-232-MV-L-42T	1	99.0	0.93
30191	GE-232-MV-N	1	99.0	1.02
72275	GE-232-MV-N	1	99.0	1.08
72276	GE-232-MV-N-42T	1	99.0	1.08
30269	GE-232-MV-N-42T	1	99.0	1.02
97709	GE-232MV-N-DIY	1	99.0	1.02
72277	GE232MV-N-DIY	1	99.0	1.08
29675	GE-232-MVPS-H	2	94.0	1.37
96720	GE232-MVPS-L	1	98.0	0.81
96714	GE232-MVPS-N	1	98.0	1.05
96717	GE-232-MVPS-N-42T	1	98.0	1.05
29671	GE-232-MVPS-XL	2	90.0	0.7
29665	GE-232-MVPS-XL-T	1	98.0	0.7
23673	GE-332-120-N	2	99.0	0.94
24165	GE-332-120-N-84T	2	99.0	0.94
29623	GE-332-120-PS-N	2	99.0	1.0
29633	GE-332-120PS-N-T	2	99.0	1.0
23674	GE-332-277-N	2	99.0	0.94
24166	GE-332-277-N-84T	2	99.0	0.94
29624	GE-332-277-PS-N	2	97.0	1.0
47549	GE332MAX-H-42T	2	99.0	1.15
71715	GE332MAX-H-42T	2	99.0	1.29
97713	GE332MAX-HSL84T	2	99.0	1.15
71714	GE332MAX-H/ULTRA	2	99.0	1.29
49776	GE332MAX-H/ULTRA	2	99.0	1.15
71718	GE332MAX-L-42T	2	99.0	0.89

*Click on product for more specification details

49708	GE332MAX-L/ULTRA	2	99.0	0.77
71717	GE332MAX-L/ULTRA	2	99.0	0.89
71422	GE332MAX-N+	2	99.0	1.0
71721	GE332MAX-N-42T	2	99.0	0.97
31053	GE332MAX-N-42T	2	99.0	0.87
97657	GE332MAX-N/CTR	2	99.0	0.87
71720	GE332MAX-N/CTR	2	99.0	0.97
23941	GE332MAX-N-DIY	2	99.0	0.87
71722	GE332MAX-N-DIY	2	99.0	0.97
71719	GE332MAX-N/ULTRA	2	99.0	0.97
49773	GE332MAX-N/ULTRA	2	99.0	0.87
30199	GE-332-MV-H	2	99.0	1.27
30296	GE-332-MV-H-42T	2	99.0	1.27
30255	GE-332-MV-L	2	99.0	0.87
30309	GE-332-MV-L-42T	2	99.0	0.87
30192	GE-332-MV-N	2	99.0	0.96
30270	GE-332-MV-N-42T	2	99.0	0.96
97710	GE-332MV-N-DIY	2	99.0	0.96
29676	GE-332-MVPS-H	2	98.0	1.28
29656	GE-332-MV-PS-H-T	2	98.0	1.28
96721	GE332-MVPS-L	2	98.0	0.77
96715	GE332-MVPS-N	2	98.0	0.98
29672	GE-332-MVPS-XL	2	98.0	0.64
23675	GE-432-120-N	3	0.94	0.94
24167	GE-432-120-N-84T	3	99.0	0.94
29625	GE-432-120-PS-N	3	99.0	0.96
29635	GE-432-120PS-N-T	3	99.0	0.96
97783	GE432-120-RES	3	5.0	0.88
71038	GE432-120RES-DIY	3	5.0	0.88
24168	GE-432-277-N-84T	3	99.0	0.94
47550	GE432MAX-H-42T	3	99.0	1.15
71724	GE432MAX-H-42T	3	99.0	1.28
49777	GE432MAX-H/ULTRA	3	99.0	1.15
71723	GE432MAX-H/ULTRA	3	99.0	1.28
71726	GE432MAX-L-42T	3	99.0	0.88
49709	GE432MAX-L/ULTRA	3	99.0	0.77
71725	GE432MAX-L/ULTRA	3	99.0	0.88
71423	GE432MAX-N+	3	99.0	1.15
71728	GE432MAX-N/CTR	3	99.0	0.94
97658	GE432MAX-N/CTR	3	99.0	0.87
71730	GE432MAX-N-DIY	3	99.0	0.94
23942	GE432MAX-N-DIY	3	99.0	0.87
71727	GE432MAX-N/ULTRA	3	99.0	0.94
49774	GE432MAX-N/ULTRA	3	99.0	0.87
30219	GE-432-MV-H	3	99.0	1.24
30303	GE-432-MV-H-42T	3	99.0	1.24
30262	GE-432-MV-L	3	99.0	0.87
30310	GE-432-MV-L-42T	3	99.0	0.87
30193	GE-432-MV-N	3	99.0	0.93
30271	GE-432-MV-N-42T	3	99.0	0.93

97711	GE-432MV-N-DIY	3	99.0	0.93
29678	GE-432-MVPS-H	3	98.0	1.26
71832	GE432-MVPS-L	3	0.98	0.71
96716	GE432-MVPS-N	3	98.0	0.96
87125	GEM232T8RS120	2	98.0	0.94
87130	GEM232T8RS277	2	98.0	0.98

CAUTIONS & WARNINGS

See list of cautions & warnings.

Return To Top

eLightBulbs.com : Part # SL54306 *Questions? Call* ***800.948.1063***

SYLVANIA

20 watt 12 volt MR16 Halogen Flood 35 Degree BAB Incandescent Sylvania Light Bulb

Sylvania 20MR16/FL35/BAB/C 12V 54306

$2.99

Our Part #:	**SL 54306**
Manufacturer:	**Sylvania**
Manufacturer Code:	**20MR16/FL35/BAB/C 12V**
Case Size:	**20** ($53.82/Case)

Energy Used:	**20 watts**
Volts:	**12**
Bulb Type:	**MR16**

eLightBulbs.com : Part # SL29395 *Questions? Call* ***800.948.1063***

SYLVANIA

30 watt 120 volt Medium Screw (E26) Base 3,000K Mini-Twist Compact Fluorescent Sylvania Light Bulb

Sylvania CF30EL/MINITWIST 29395

Energy Saver!
Replaces a **120** watt Incandescent Light Bulb

$9.99

Our Part #:	**SL 29395**
Manufacturer:	**Sylvania**
Manufacturer Code:	**CF30EL/MINITWIST**
Case Size:	**12** ($107.89/Case)

Light Output:	**2,000 lumens**
Energy Used:	**30 watts**
Average Lifetime:	**6,000 hours**
Volts:	**120**
Bulb Type:	**T4**
Base Type:	**Medium Screw (E26)**
Color Temperature:	**3,000K**
CRI:	**82**
Length:	**5.1 inches**

eLightBulbs.com : Part # SL11223 *Questions? Call **800.948.1063***

SYLVANIA

40 watt 120 volt A19 Medium Screw (E26) Base Clear Incandescent Sylvania Light Bulb 2 Pack

Sylvania 40A/CL/RP 120V 11223

$3.14

Our Part #:	**SL 11223**
Manufacturer:	**Sylvania**
Manufacturer Code:	**40A/CL/RP 120V**
Case Size:	**24** ($67.82/Case)

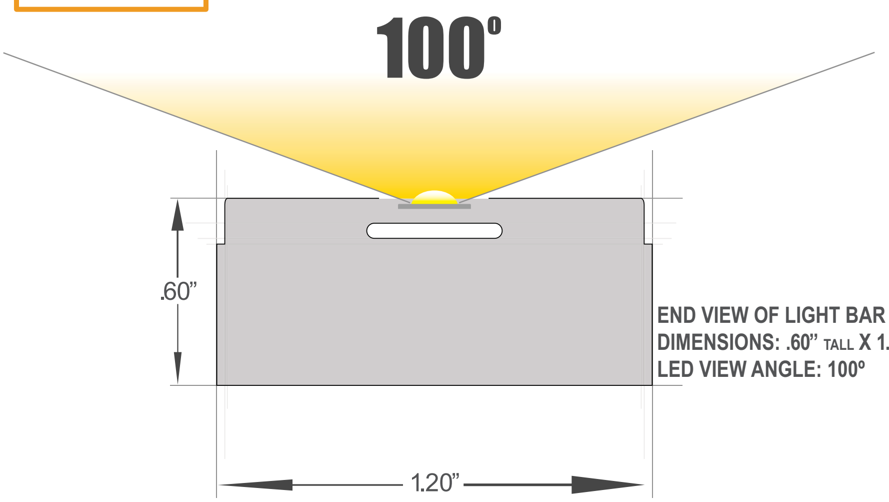
Light Output:	**460 lumens**
Energy Used:	**40 watts**
Average Lifetime:	**1,500 hours**
Volts:	**120**
Bulb Type:	**A19**
Base Type:	**Medium Screw (E26)**
Color / Finish:	**Clear**
Color Temperature:	**2,850K**
CRI:	**100**
Length:	**4.45 inches**

PIRANHA 36 LED LIGHT BAR WHITE

HOW TO READ AN LED POWER PART NUMBER:

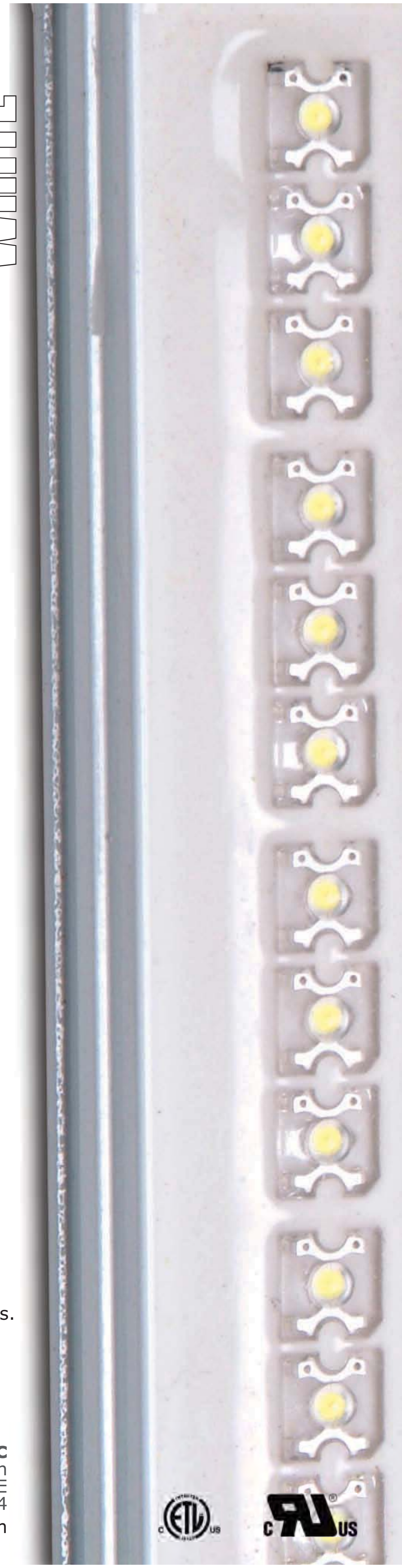
LB 36 1 - WWW P - 100 - 24

- LB IS SIMPLY TO IDENTIFY THE PART NUMBER INTO THE LIGHT BAR CATEGORY.
- THESE TWO NUMBERS ARE HOW MANY LED LIGHTS PER FOOT ARE IN THE LIGHT BAR.
- THIS NUMBER INDICATES THE LENGTH OF THE LIGHT BAR IN FEET. IT WILL EITHER BE 6",1, 2, 3, OR 4.
- THESE THREE LETTERS REPRESENT THE COLOR OF THE LED LIGHTS IN THE LIGHT BAR.
- THIS LETTER STANDS FOR THE TYPE OF LED USED. P = PIRANHA STYLE SUPER FLUX LED. 5 = 5 INCH LED. O = OVAL 100º/40º LED.
- THIS NUMBER REPRESENTS THE VIEW ANGLE OF LIGHT EMITTED FROM THE LED.
- 12 VDC or 24 VDC



END VIEW OF LIGHT BAR
DIMENSIONS: .60" TALL X 1.20" WIDE
LED VIEW ANGLE: 100º

- This product is ETL Listed and confirms to UL Standard 1598.
- Certified to CAN/CSA Standard 22.2 No. 250.0-04.
- High-Quality LED based Light Bars are available in an array of colors and lengths.
- Choose from 6 inch to 4 foot long lengths with your choice of LED.
- Low-Wattage, Low-Voltage and very Low-Heat with 12VDC or 24VDC Operation.
- White Color Kelvin Temperatures from 2800°K, 3500°K, 5000°K & 8000°K.
- Mono Colors available in Red, Amber, Blue & Green.
- RGB with DMX compatible controllers also available for your color changing projects.
- Light Bars have LED view angles that are customizable from 20° to 120°.
- Ridged Aluminum Light Bars come fully silicone potted for added durability.
- User friendly, easy installation with quality end-to-end connections and brackets.
- Suitable for damp locations.



LED Power, Inc
17875 Sky Park North
Suite E
Irvine, CA 92614
949 679 0031 PHONE **949 679 0037** FAX info@ledpower.com www.ledpower.com

WHITE

LIGHT BAR ELECTRICAL SPECIFICATIONS

PART NUMBER	DESIGN VOLTAGE		TYPICAL CURRENT		TYPICAL WATTS	MAX (LOAD) AMPS PER RUN	MAX (LOAD) WATTS PER RUN	
			12V	24V			12V	24V
LB361-XXXP-100-XX	12 VDC	24 VDC	0.33A	0.17A	4W	5 Amps	60W	120W
LB362-XXXP-100-XX			0.66A	0.33A	8W			
LB363-XXXP-100-XX			0.99A	0.50A	12W			
LB364-XXXP-100-XX			1.33A	0.67A	16W			

LIGHT BAR DIMENSIONS

PART NUMBER	LEDS PER FOOT	LEDs	LIGHT BAR LENGTH	ALUMINUM EXTRUSION
LB361-XXXP-100-XX	36	36	L = 12.5 INCH	1.20” Wide 0.60” High
LB362-XXXP-100-XX		72	L = 24.5 INCH	
LB363-XXXP-100-XX		108	L = 36.5 INCH	
LB364-XXXP-100-XX		144	L = 48.5 INCH	

LED SPECIFICATIONS

PART NUMBER	LED COLOR	TYPICAL KELVIN	VIEW ANGLE	TYPICAL LUMENS PER FOOT
LB36X-WASP-100-XX	Super Warm White	2800ºK	100º	130 lm
LB36X-WARP-100-XX	Warm White	3500ºK	100º	144 lm
LB36X-WCOP-100-XX	Cool White	5000ºK	100º	159 lm
LB36X-WBTP-100-XX	Bright White	8000ºK	100º	172 lm

LED Power, Inc
17875 Sky Park North
Suite E
Irvine, CA 92614

949 679 0031 PHONE **949 679 0037** FAX info@ledpower.com www.ledpower.com

The world's brightest **LED** MR16 Lamp

80% energy savings

Only 4.7 Watts

Superior, patented Hybrid optics

Environmentally safe: contains no Mercury (Hg), no Lead (Pb). RoHS compliant

Long Life: 70,000 hours

IMS Lighting has succeeded where others have failed. By utilizing highly efficient, patented Hybrid optics the IMS LED MR16 lamp provides an energy efficient replacement to halogen MR16s.

At 70,000* hours its projected life is 23x the life span of an average halogen MR16, radically reducing maintenance costs and increasing system reliability.

High energy efficiency and long operating life result in 80% lower operating costs.**

The IMS LED MR16 emits no harmful ultraviolet (UV) or infrared (IR) light. The unit is constructively safe - there is no glass to break upon impact and it doesn't run as hot as halogen MR16s.

Fits in most standard luminaires, but may not fit all.

Fully dimmable.

First LED MR16 to qualify as a High Efficacy Lamp per **California Title 24**. This would require a modification to our lamp base. This modification is pending.

US Patent No. 6,986,593; worldwide patents pending, including Europe, China and Japan.

* Projected life based on 70% lumens maintenance, DC power in a free air flow fixture (track light).

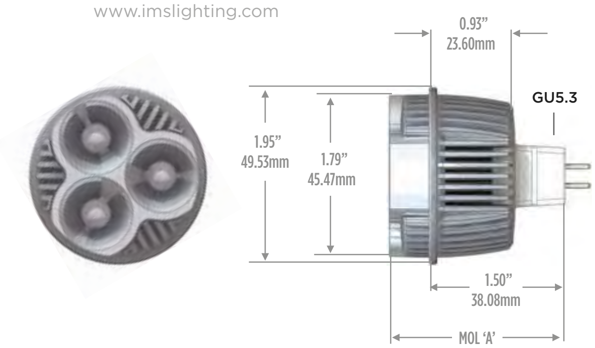
** Based on 12 hours of use per day, electricity cost of $0.12/KWh, and $2 in labor towards bulb replacement, 3,000 hour halogen MR16.

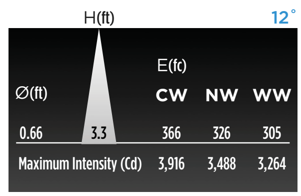
IMS Lighting

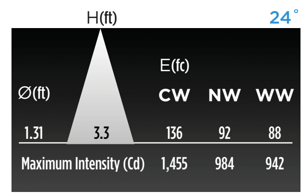
IMS Lighting

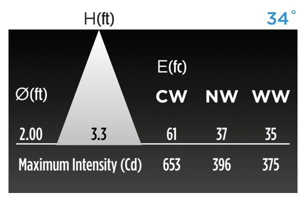
LED MR16 Lamp

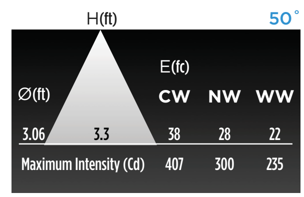
18242 McDurmott West, Suite J
Irvine, CA 92614, USA
www.imslighting.com











Specs: 12V, 4.7W, AC and DC, 50-60Hz.

Fully dimmable.

Works best with regulated 12V DC systems. Also compatible with AC track lighting with magnetic transformers. Not compatible with AC track lighting with integral electronic transformers due to the unit’s low power consumption of less than 5W.

Environmentally safe: contains no Mercury (Hg), no Lead (Pb). RoHS compliant.

Graphs **CW** = cool white, **NW** = natural white, **WW** = warm white

Daylight White **5,600K** LEDs available on special order. Please call for information and minimum order quantities

Thermal decline and color shift
Data published in this file is measured at turn-on. The nature of a solid-state lighting device is that rising temperature cause a slight decrease in brightness and a color shift on the Kelvin scale. For all inclusive data we refer to our file IMS_MR16_thermal.pdf which can be found on www.imslighting.com

Watts (W)	Could replace (W)	SKU	Voltage (V)	LED color	Color temperature* (K)	Beam angle	Beam spread	Luminous flux** (L)	MOL ‘A’ (inches)	(mm)	Projected life (h)
4.7	25	MR16-12-C-S	12	cool white	6,500	12°	spot	213	1.94”	49.28	70,000
4.7	25	MR16-24-C-S	12	cool white	6,500	24°	narrow flood	213	1.89”	48.00	70,000
4.7	25	MR16-34-C-S	12	cool white	6,500	34°	flood	213	1.90”	48.26	70,000
4.7	25	MR16-50-C-S	12	cool white	6,500	50°	wide flood	213	1.82”	46.23	70,000
4.7	20	MR16-12-N-S	12	natural white	4,300	12°	spot	160	1.94”	49.28	70,000
4.7	20	MR16-24-N-S	12	natural white	4,300	24°	narrow flood	160	1.89”	48.00	70,000
4.7	20	MR16-34-N-S	12	natural white	4,300	34°	flood	160	1.90”	48.26	70,000
4.7	20	MR16-50-N-S	12	natural white	4,300	50°	wide flood	160	1.82”	46.23	70,000
4.7	20	MR16-12-W-S	12	warm white	3,200	12°	spot	139	1.94”	49.28	70,000
4.7	20	MR16-24-W-S	12	warm white	3,200	24°	narrow flood	139	1.89”	48.00	70,000
4.7	20	MR16-34-W-S	12	warm white	3,200	34°	flood	139	1.90”	48.26	70,000
4.7	20	MR16-50-W-S	12	warm white	3,200	50°	wide flood	139	1.82”	46.23	70,000

*Color temperature may vary per LED. **Average luminous flux. **Exit lumens** as measured exiting the optics, not input lumens as measured at the LED. Luminous flux may vary per LED. Specifications on this sheet may be subject to change for design and specification improvement without prior notice.

Call our sales department for more information and pricing: 949.567.1930 x228

sales@imslighting.com

Save 80% energy

Long life: 70,000 hours

Environmentally safe: no Mercury or Lead

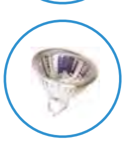


The world's brightest LED MR16 lamp

Clear benefits

- Replace existing halogen MR16 lamps and save 80% energy.
- Produces 80% less heat: reduce high air conditioning costs.
- Emits no harmful ultraviolet (UV) or infrared (IR) light.
- Available in following beam angles: Spot (12˚), Narrow Flood (24˚), Flood (34˚) and Wide Flood (50˚).
- Available in Warm White, Natural White and Cool White in all beam angles. See product brochure.
- For AC and DC circuits. Fully dimmable. 12V 50/60Hz 4.7W
- RoHS compliant

Safer than CFL lamps - IMS LED MR16 lamps don't shatter upon impact, and contain no harmful Mercury (Hg).



IMS LED MR16 lamps save up to 80% energy and unlike common halogen MR16s qualify as a High Efficacy Lamp per California Title 24.

IMS Lighting has succeeded where others have failed. By utilizing highly efficient, patented Hybrid optics the IMS LED MR16 lamp provides an energy efficient replacement to halogen MR16s.

US Patent No. 6,986,593; worldwide patent pending, including Europe, China and Japan.

Call our sales department for pricing and more information: 949.567.1930 x228

sales@imslighting.com

IMS Lighting

18242 McDurmott West, Suite J
Irvine, CA 92614, USA
www.imslighting.com

Patented optics make the difference

The IMS LED MR16 Lamp is the **world's brightest** LED MR16 lamp thanks to its **superior, patented optics**. The optics achieve maximum collection and distribution efficiency.

US Patent No. 6,986,593; worldwide patent pending, including Europe, China and Japan.

Reliable construction

The construction of the IMS LED MR16 Lamp is a careful synthesis of electronic components, adequate heat sink and superior optics. Our electronic components are designed to last at least 70,000* hrs, our large heat sink is designed to keep the LED lamp at a constant low temperature. Compare to common LED MR16 lamps where limited life of the electronic components and inadequate heat sinks can lead to **early catastrophic failure**.

High energy savings

The IMS LED MR16 Lamp provides up to **80% energy savings**.

First LED MR16 to qualify as a **High Efficacy Lamp per California Title 24**. This would require a modification to our lamp base. This modification is pending.

80% less power consumption results in **80% less heat production**; heat that normally raises the ambient temperature in commercial environments. This excessive and unnecessary heat produced by halogen MR16s is commonly neutralized by running costly air conditioning. Switching to IMS LED MR16 Lamps **reduces high air conditioning costs**.

Excellent return on investment

ROI is reached after 17 months of use. Calculations are based on 12 hours of use per day, electricity cost of $0.12/KWh, and $2 in labor towards bulb replacement. We used an average life span of 3,000 hrs for a halogen MR16, and 70,000* hrs projected life span for the IMS LED MR16 Lamp.

By utilizing the highly efficient, patented Hybrid optics the IMS LED MR16 Lamp provides an energy efficient replacement to halogen MR16s. While driven at a mere 4.7 Watts it offers comparable light output at **80% lower operating cost**.

Operating cost are just 1/8 of a cent per hour, compare to 6/10 of a cent per hour for an average 50W halogen MR16.

Our projected lamp life is 70,000* hrs. An average halogen MR16 has a life span of merely 3,000 hrs. The IMS MR16 LED Lamp offers a **23x longer projected life span**, radically reducing maintenance costs and increasing system reliability.

Reducing the total power consumption of a light system by 80% the use of IMS LED MR16 Lamps also **reduces high transformer costs by about 80%**.

Best light quality

The IMS LED MR16 Lamp produces the **best light pattern of any existing MR16**, halogen or LED. The light pattern is smooth and does not suffer from overlap issues - common to LED lamps with multiple LEDs.

Environmentally safe

Unlike CFL lamps IMS LED MR16 Lamps contain no Mercury (Hg) or Lead (Pb). It is an **environmentally safe product**. A CFL is a good product but contains Mercury (Hg), which can pose a health hazard and impacts our environment when disposed of in landfills.

The solder used in our circuitry is lead-free and fulfills strict European standards: **RoHS compliant**.

The IMS LED MR16 Lamp contains no glass, or other components that could shatter upon impact.

The IMS LED MR16 Lamp produces **no harmful Infrared (IR) and Ultraviolet (UV) radiation**.

Broad application

The IMS LED MR16 Lamp is designed to fit in most standard luminaires, but may not fit all. Please check specifications.

The IMS LED MR16 Lamp is fully dimmable.

The unit works best with regulated 12 Volt DC power supply. Also compatible with AC magnetic transformers. Not compatible with AC track lighting with integral electronic transformers due to the unit's low power consumption. Do not exceed 12.5 Volts. The unit works for both 50 and 60 Hz AC.

Projected life span

Based on 70% lumens maintenance, preferred new standard for LED lighting:

DC power in a free air flow fixture	70,000 hours
DC power in a can light	40,000 hours
AC power in a free air flow fixture	42,000 hours
AC power in a can light	25,000 hours

Projected life span based on 50% lumens maintenance, the current standard for halogen lighting:

DC power in a free air flow fixture	130,000 hours
DC power in a can light	75,000 hours
AC power in a free air flow fixture	77,000 hours
AC power in a can light	50,000 hours

* Projected life based on 70% lumens maintenance, DC power in a free air flow fixture (track light).

IMS Lighting

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Irvine, CA 92614, USA
T 949.567.1930 sales x228
F 949.567.1940

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Lighting a brighter future.

Solid State LED PAR30-12 Lamp

Features:
Super Bright 13-Watt LED Lamp
DLR – Direct Lamp Replacement
Low Heat - Excellent Heat Sink Performance
No UV Light Radiation
3-Year Warranty

Applications:
Hotels and Casinos
Office and Commercial Buildings
Replaces Standard Can or Track Lighting
Entertainment Lighting
Architectural Lighting
Retail Store Lighting
Art Galleries and Museums

Specifications:
Voltage Requirement: 120-Volt AC
Power Consumption: 13 Watts
Beam Angle: 25°
2800°K Super Warm (590 lumens typical)
3500°K Warm White (600 lumens typical)
5000°K Cool White (720 lumens typical)
Standard Edison Base
Not Dimmable

Part Numbers:
AL-PAR3012-25-SW (2800°K)
AL-PAR3012-25-WW (3500°K)
AL-PAR3012-25-CW (5000°K)

Custom Housing Colors Available For Special Orders

LED Power, Inc.
17875 Sky Park North, Suite E Irvine, CA 92614
Tel: 949-679-0031 Fax: 949-679-0037
www.ledpower.com

Appendix E

Feedback Surveys

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineering DATE 11-19-08

NAME (Optional) Bob Woodfin

A change was recently made to some of the lighting in the chandelier, the Plaza B Hallway and in the spa at this location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

___ TEST AREA 1: Chandelier	___ TEST AREA 2: Plaza B	X TEST AREA 3: Spa

For the questions below, circle the response that most closely matches your answer. Ratings are from 1 to 10; 1 being the LOWEST score and 10 being the HIGHEST score. Comments are encouraged.

1. Did you notice the lighting change before this survey made you aware of it?

   Did Not Notice — Noticed

   1 2 3 4 5 6 7 8 9 10

2. Have you overheard or otherwise received any direct feedback from store customers about the lighting change?

   Yes / No — Feedback: Negative / Neutral / Positive

3. In general, does the replacement lighting system create more or less visual interest in the merchandise than was provided by the previous lighting system?

   Creates Less Visual Interest — Creates More Visual Interest

   1 2 3 4 5 6 7 8 9 10

4. In general, does the replacement lighting system seem to provide more light, the same amount of light, or less light than was provided by the previous lighting system?

   Provides Less Light — Same Amount — Provides More Light

   1 2 3 4 5 6 7 8 9 10

5. In general, how satisfied are you with the replacement lighting system?

   Not Satisfied — Very Satisfied

   1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: The bar (Led) lights are great, the MR-16 replacement works great!

CUSTOMER FEEDBACK SURVEY – LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineering DATE 11-19-08

NAME (Optional) Bob Woodfin

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X TEST AREA 1: Chandelier	___ TEST AREA 2: Plaza B	___ TEST AREA 3: Spa

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   1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: Made a interesting effect in the chandelier - The boss likes the modern look - color/temperature needs to be matched with lighting in nearby areas.

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineering DATE 11-19-08

NAME (Optional) Bob Woodson

A change was recently made to some of the lighting in the chandelier, the Plaza B Hallway and in the spa at this location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

___ TEST AREA 1: Chandelier	X TEST AREA 2: Plaza B	___ TEST AREA 3: Spa

For the questions below, circle the response that most closely matches your answer. Ratings are from 1 to 10; 1 being the LOWEST score and 10 being the HIGHEST score. Comments are encouraged.

1. Did you notice the lighting change before this survey made you aware of it?

Did Not Notice — Noticed

1 2 3 4 5 6 7 8 9 10

2. Have you overheard or otherwise received any direct feedback from store customers about the lighting change?

Yes / No Feedback: Negative / Neutral / Positive

maybe a little dim – color/temperature too high

3. In general, does the replacement lighting system create more or less visual interest in the merchandise than was provided by the previous lighting system?

Creates Less Visual Interest — Creates More Visual Interest

1 2 3 4 5 6 7 8 9 10

4. In general, does the replacement lighting system seem to provide more light, the same amount of light, or less light than was provided by the previous lighting system?

Provides Less Light — Same Amount — Provides More Light

1 2 3 4 5 6 7 8 9 10

5. In general, how satisfied are you with the replacement lighting system?

Not Satisfied — Very Satisfied

1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

Would not recommend it — Would recommend it

1 2 3 4 5 6 7 8 9 10

Comments: for the right area, this bulb seems to be a

a good choice – Long Lasting?

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Property operations /Asst. Chief DATE 11-20-08

NAME (Optional) Jorge Leiva

A change was recently made to some of the lighting in the chandelier, the Plaza B Hallway and in the spa at this location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

___ TEST AREA 1: Chandelier	___ TEST AREA 2: Plaza B	✓ TEST AREA 3: Spa

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   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: ______

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Property operations / Asst. Chief. engineer DATE 11-20-08

NAME (Optional) Jorge Lewis.

A change was recently made to some of the lighting in the chandelier, the Plaza B Hallway and in the spa at this location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

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   Not Satisfied — Very Satisfied

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6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: ______________________

CUSTOMER FEEDBACK SURVEY – LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Property operations/Asst. Chief DATE 11-20-08

NAME (Optional) Jorge Leiva

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For the questions below, circle the response that most closely matches your answer. Ratings are from 1 to 10; 1 being the LOWEST score and 10 being the HIGHEST score. Comments are encouraged.

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   1 2 3 4 5 6 7 8 9 10

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   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: This lights NEED ~~more~~ TO be more Brighter. Color was good.

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineer/Asst. Chief DATE 11/19/08

NAME (Optional) Rodrigo Ramirez

A change was recently made to some of the lighting in the chandelier, the Plaza B Hallway and in the spa at this location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

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   Not Satisfied — Very Satisfied

   1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: The light fixture is not visible and it reflects the same light as the florecent bulbs from the ceiling

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineer/Asst. Chief DATE 11/19/08

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   1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: IT is a big contrast to the other 2 chandeliers in the area, well suited for display.

CUSTOMER FEEDBACK SURVEY –
LED LIGHTING TEST: HILTON (SAN FRANCISCO)

DEPARTMENT/POSITION Engineer/Asst. Chief DATE 11/19/08

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   1 2 3 4 5 6 7 8 9 10

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   Not Satisfied — Very Satisfied

   1 2 3 4 5 6 7 8 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

   Would not recommend it — Would recommend it

   1 2 3 4 5 6 7 8 9 10

Comments: The PLAZA B area is dark and the new lights looked darker.