U.S. DEPARTMENT OF
ENERGY

PNNL-20019

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

Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps at Intercontinental Hotel in San Francisco, CA

N Miller K Curry

November 2010

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Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps at Intercontinental Hotel in San Francisco, CA

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

Study Participants:
Pacific Northwest National Laboratory
U.S. Department of Energy
Pacific Gas & Electric
Intercontinental Hotel Group

N Miller K Curry

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Preface

This document is a report of observations and results obtained from a lighting demonstration project conducted under the U.S. Department of Energy (DOE) GATEWAY Demonstration Program. The program supports demonstrations of high-performance solid-state lighting (SSL) products in order to develop empirical data and experience with in-the-field applications of this advanced lighting technology. The DOE GATEWAY Demonstration Program focuses on providing a source of independent, third-party data for use in decision-making by lighting users and professionals; this data should be considered in combination with other information relevant to the particular site and application under examination. Each GATEWAY Demonstration compares SSL products against the incumbent technologies used in that location. Depending on available information and circumstances, the SSL product may also be compared to alternate lighting technologies. Though products demonstrated in the GATEWAY program have been prescreened and tested to verify their actual performance, DOE does not endorse any commercial product or in any way guarantee that users will achieve the same results through use of these products.

Executive Summary

This report describes the process and results of a demonstration of solid-state lighting (SSL) technology in a high-end hotel application, under the U.S. Department of Energy GATEWAY Solid-State Lighting Technology Demonstration Program. At the InterContinental Hotel (888 Howard Street, San Francisco), multi-lamp linear wall-grazing luminaires, mono-point track lights, and recessed adjustable downlights, all using either 20W or 30W halogen MR16 lamps, were retrofitted with 6W LED MR16 replacement lamps by CRS Electronics. In addition, two kinds of recessed downlights using 75W halogen PAR30 lamps were retrofitted with 11W LED PAR30 replacement lamps by Philips Lighting.

The LED MR16 and PAR30 products were installed in several areas of the hotel where luminaires are in continuous operation 24/7, where ceiling heights are 9' or lower, where dimming was not absolutely essential, and where lower output lamps were desirable or acceptable. These included the 1st Floor Registration Desk area and Elevator Lobby, the 3rd and 4th Floor Conference Room emergency-circuit downlights, and the 7th through 9th floor elevator lobbies and the Guest Room Corridor artwork accent lighting. On the first five floors, all lighting is controlled by a multi-space architectural dimming control system, except for luminaires on emergency circuits which operate at full output at all times. On higher floors, light output is fixed at full output.

LED replacement lamps have the potential of saving substantial energy, but at this point are challenged in their light output and color quality. The lamps for the InterContinental Hotel were selected through a multi-step process for color quality, lumen output and candela distribution, beam appearance, color consistency, flicker, and compatibility with the different transformers in the existing downlights and track heads. The hotel's strict standards for quality made this a critical process. The selected 6W LED MR16 (avg. 285 lumens, 44 LPW) delivers lumens, color, and candela distribution similar to that of a 20W premium halogen MR16. The 11W LED PAR30 (avg. 440 lumens, 45 LPW) is approximately equivalent to a 40W PAR30 halogen lamp at full output.

The capital and energy costs of the retrofit were projected over a three year period. The initial cost of the LED lighting replacements was $19,396 for lamps and group relamping labor. Energy cost, at $0.13 per kWh melded rate, for the retrofitted areas of the hotel is $1,975 annually (16,136 kWh), compared to $6,361 annually (51,975 kWh) for the original halogen lamping. The present value life-cycle cost of the LED installation is $28,294, compared to $48,992 for the halogen lamping. This equates to a payback of 1.1 years, with an adjusted internal rate of return of 39.67%.

A complication to the financial and illuminance calculations is that the public areas of the 1st floor and conference floors were controlled with a large architectural dimming system, and output levels for the halogen lighting had been set to low levels when the system was commissioned. In many cases these levels were lower than the staff or owners would have liked, but they were unaware that the levels could be changed, and the facilities staff was hesitant to reprogram the settings. Note that throughout this report, comparisons will be made to the dimmed halogen setting for these floors.

The LED replacement lamps yielded mixed results when compared to the illuminance levels produced by the original halogen lamps. The 11W PAR30 LED lamps used at full output in the conference rooms delivered half the illuminance of the original 75W halogen lamps. However, when used on the main floor in areas where halogen lamp circuits were consistently dimmed to lower output, the LED PAR30 lamps delivered higher illuminance levels than the dimmed halogen counterparts. Similarly, the LED MR16 lamps delivered dramatically more light than the dimmed 20W lamps used in the wall-grazing lights behind the Registration Desk, but in elevator lobbies and guest corridors, the LED MR16 lamps delivered approximately 50% less light than the original undimmed 30W halogen lamps. (The dimming system levels were set to full output after the LED lamps were installed because the LED lamps were not dimmable.)

For high-end hospitality applications, illuminance levels and efficacy are not the primary considerations in selecting lighting sources and luminaires. Image, luxury, service, visual interest, and beautiful materials and objects are the reason patrons choose this hotel. The hotel operates 24 hours a day and generally, maintenance must be performed at night at high cost. For this reason, reduced relamping frequency is of high value to the hotel to reduce labor costs. This Intercontinental Hotel Group hotel is going beyond the norm by pursuing LEED EBOM (Leadership in Energy and Environmental Design – Existing Buildings Operation and Maintenance) certification, and it prides itself on progressive environmental measures. Consequently, reducing energy use is paramount, but it must be done without sacrificing the aesthetics and functionality of the designed spaces. The LED lamp solutions have received high aesthetic praise and acceptability or they would not have remained in their sockets.

The Registration Desk staff, original lighting designer, hotel owners, facility engineers, security staff, and owners have all provided very positive feedback. The one criticism of the retrofit project is that late at night, the Registration Desk area space looks and feels “too bright,” as the LED retrofit lamps do not dim well and are set at full output. However, they are pleased with the additional visibility that comes with higher light levels on desk areas where reading and writing tasks are performed, and happy that guest faces are easier to see in person and through security cameras.

This successful installation of LED products did not occur without some disappointments, hiccups and surprises. Dozens of products initially evaluated for use exhibited poor color, flicker, abnormally low output or no output at all, or other unexpected behavior, such as fire-alarm-type strobing when dimmed during the initial install of the retrofit project. In spite of preliminary screening, and an extensive mockup phase, there were still lessons to be learned in the final installation. In summary, LEDs can perform beautifully in retrofit applications if located wisely, but at the moment require additional homework and testing of potential lamps with the actual installed luminaires and control systems.

As of this publication date, these replacement lamps have operated for approximately 3000 hours without incident. Sample lamps are scheduled to be removed from the installation and sent for photometric testing after 1000 hours, 3000 hours, 6000 hours, and 9000 hours of operation, to document color and light output performance over time. These will be added to this report as they become available.

Update after 1000 hour lamp testing
Laboratory testing showed the performance of both lamp types to be very stable. Two lamps of each type were tested.
The PAR30 LED lamp lumen output rose by less than 2%, CCT rose by less than 15K (imperceptibly cooler), CRI varied by less than 1 point, and Watts dropped by less than 3%.
The MR16 LED lamp lumen output rose by less than 1%, CCT rose by less than 10K (imperceptibly cooler), CRI varied by less than 1 point, Duv varied by less than 0.0001, and Watts dropped by less than 1%.

Update after 3000 hour lamp testing
Laboratory testing showed the performance of both lamp types to be very stable. Two lamps of each type were tested.
The PAR30 LED lamp lumen output rose by less than 4%, CCT rose by less than 25K (imperceptibly cooler), CRI varied by 1 point or less, Duv varied by less than 0.0012, and Watts dropped by less than 1.5%.
The MR16 LED lamp lumen output dropped by less than 3.7%, CCT rose by less than 22K (imperceptibly cooler), CRI varied by less than 1 point, Duv varied by less than 0.0005, and Watts dropped by less than 3%.

Reserved for update after 9000 hour lamp testing

Reserved for update after 6000 hour lamp testing

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1.0 Introduction

The InterContinental Hotel on Howard Street in San Francisco is a world-class contemporary hotel built in 2008, with a coveted Michelin Guide one-star restaurant, luxury spa, and conference facilities. Dramatic lighting brings out the beauty of rich wood finishes, furnishings, and blown glass art objects. As a destination hotel, the InterContinental is proud of its image and its environmentally-conscious reputation. In 2009, Pacific Gas & Electric (PG&E) suggested the hotel as a site for demonstrating LED replacement lamps. Having been disappointed with some earlier LED products, the hotel engineer was reluctant to commit to the project unless he received confirmation from the owners, managers, and the original project lighting designer that the aesthetic results would be equivalent to or better than the original halogen lighting system. The project team went through several steps to visually evaluate LED product options, then install the best of these in the hotel for a week before committing to a longer-term replacement of lamps.

Figure 1.1. Photo of InterContinental Hotel Lobby with Original Halogen Lamping in Registration Desk Area. A complete relamping of halogen lamps was carried out to ensure optimum light output. **www.kenricephoto.com**

Project objectives included maintaining or improving lighting quality as evaluated through a review of appearance of space and objects, color quality, glare control, flicker, appropriate beam spread for the application, and appropriate light levels for task areas and signage, etc. The project team also agreed that the solution should be cost-effective and energy-efficient, ideally with a simple payback period of 2 years or less. Any compromise in safety and security would not be acceptable. These issues would be documented through before and after illuminance measurements and energy calculations, but also through the honest feedback of the owners, managers, security manager, hotel staff, guests, and the original lighting designer, Michael Souter of Luminae Souter Lighting Design.

Figure 1.2. Photo of InterContinental Hotel Lobby Registration Desk Area with LED Replacement Lamps. **www.kenricephoto.com**

2.0 Methodology

2.1 Steps for this GATEWAY Demonstration

PG&E identified a customer with high aesthetic criteria and environmental awareness that operated a building with an installed base of halogen lamps. In brief, the following steps were undertaken during the course of this GATEWAY project:

- Identify lamps and areas in the building that are candidates for LED replacement lamps
- Write technical performance specifications for the LED replacement lamps. Procure LED lamp samples that approach that performance from vendors.
- Round 1 testing. Visually valuate the candidate lamps side-by-side with the incumbent halogen lamps. Evaluation criteria include color quality for skin tones and wood finishes, beam quality, comparable intensity and beam spread, availability, NRTL (Nationally Recognized Testing Laboratory) listing for electrical safety,LM-79 reported performance, and flicker. Evaluation team identifies best lamps for Round 2 mockup tests.
- Procure six lamp samples of each Round 2 candidate lamp for mockup in hotel elevator lobbies. Hotel staff to install mockup lamps for viewing by evaluation team in late February 2010.
- Round 2 testing. Team to see and evaluate LED and halogen incumbent lamps installed without knowing the make/model of the lamps. Control circuits with LED lamps are set to 100% output on dimming system. (This process eliminates several LED lamp options because of color, light output, or visible flicker problems.)
- Lamps that survive this test are then tested for “fit” and function in different luminaire types. Lamps that do not function (i.e. light up) on all luminaire types are dropped from consideration.
- Successful lamps are installed in hotel areas for a week-long test. Poor-performing lamps are eliminated as candidates for the final installation.
- Complete set of LED replacement lamps are ordered, and 8 samples of each lamp type are labeled and sent to photometric lab for baseline testing before installation in the hotel.
- Areas selected for the testing of LED lamps are relamped with new halogen lamps.
- Hotel employees are surveyed on the halogen lighting.
- Hotel is photographed with halogen lamping. “Before” illuminance measurements are taken.
- Hotel areas are relamped with LED replacement lamps overnight, April 22nd.
- Hotel areas are photographed with LED replacement lamps. “After” illuminance measurements are taken.
- Hotel employees are surveyed on lighting once again.
- Feedback from security manager, hotel engineer, developer, owner, and lighting designer is documented.
- Two of each lamp type from the sample set of LED lamps are scheduled to be uninstalled and sent to a photometric lab for re-testing after 1000 hours of operation, 3000 hours, 6000 hours, and 9000 hours of operation in order to track long-term performance. Hotel engineer to provide feedback on any color changes, instability, premature failures, etc.
- Document case study in a GATEWAY report, with updates to report results of long-term testing and in-situ performance.

2.2 Demonstration Site Description and Background

The hotel, located at 888 Howard Street in San Francisco, was completed in 2008, and was designed with high-efficiency building envelope, heating, cooling, machinery, kitchen equipment, and lighting systems. The lighting design met strict Title 24 energy code requirements, using fluorescent luminaires for general lighting with halogen luminaires for accent lighting in most spaces. Only a few high-visual-importance spaces such as the entrance lobby and Registration Desk areas use halogen luminaires for general lighting.

The public areas of the hotel, including elevator lobbies and guest floor corridors, operate 24 hours a day, 7 days a week, which means these spaces contribute significantly to the building's electric energy use. PG&E reported that the hotel's melded electrical rate is $0.13 per kWh. (A melded rate takes demand charges and any fluctuating usage charges into account.)

Because the hotel public spaces are continuously occupied, spot relamping must be done at night when the work is least likely to disturb guests and activities. Consequently, the per-lamp relamping cost is high, approximately $50 per lamp.

The InterContinental Hotel San Francisco has made a serious commitment to environmental responsibility and is working toward the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design -Existing Buildings Operation and Management (LEED-EBOM) certification. They were pleased to be involved in this demonstration project because the hotel sought to learn a great deal about LEDs that could be applied throughout their hotel and to other hotels in their group, to save energy without sacrificing visual quality. One of the measures they had already taken was to reduce lighting wattage by replacing 50W MR16 halogen lamps with 30W Infrared ("IR") halogen lamps by Philips, so all comparisons to MR16 accent lights in this report are relative to that newer lamping. (The 20W MR16 halogen lamps used in wall grazing of the wood walls in the Registration Desk had remained as originally specified.)

2.3 Round 1 - LED Lamp Procurement and Evaluation

The evaluation process began in January 2010. The evaluation team comprised a mix of designers and engineers from PG&E and PNNL, plus the chief hotel engineer, one of the project developers and the original project lighting designer[1]. The team identified the most common halogen lamps in the hotel, and PNNL wrote a specification for the ideal replacement lamp types. (See Appendix A) PG&E issued these to vendors, requesting three samples (as a check on product consistency), product literature, and photometric test reports on each submitted lamp type. Integral LED lamps were procured as replacements for the following:

- 120W PAR38 halogen lamp, 120V, 30° Flood distribution, medium base
- 75W halogen AR111 lamp, 12V, 10° Spot distribution, space-connector base
- 75W halogen PAR30 longneck, 120V, 25° Narrow Flood distribution, medium base**

[1] Attendees: Thor Scordelis, Steven Mesh, Juan Miller, PG&E; Mary Matteson Bryan, consultant to PG&E; Michael K. Souter, Luminae Souter Lighting Design; Harry Hobbs, John Buss, InterContinental Hotel Group; Ku'uipo Curry, Naomi Miller, Pacific Northwest National Laboratory.

- 75W halogen PAR30 shortneck, 120V, 25° Narrow Flood distribution, medium base**
- 30W IR halogen MR16, 12V, 25° Narrow Flood distribution, bi-pin base
- 20W halogen MR16, 12V, 15° Narrow Spot Distribution, bi-pin base

(** Samples informally procured because need was identified late in the process)

PG&E received submissions from vendors, and a date was booked at the hotel for doing side-by-side visual and numerical evaluations. Shortly before that date the team learned that many of the luminaires thought to use PAR38 lamps actually accepted only PAR30 lamps. So, the team informally procured a few PAR30 LED lamps for evaluation. Although PAR38 lamps were considered, LED replacements for these lamps would not have been appropriate for this project because full-range dimming was required for ballrooms that used these lamps, and the light output of the submitted PAR38s was far below the halogens they were meant to replace. (At that time, few smoothly-dimming LED lamps were available.) Consequently, PAR38 lamps were eliminated from further testing and from this report.

2.3.1 Problems in Procuring and Logging Lamps for Evaluation

PG&E issued the request for LED replacement lamps to 40 manufacturers, received the lamps and technical information submissions, and produced a spreadsheet documenting the lamps and their information. Difficulty was encountered in matching up the number on the lamps with the corresponding LM-79 test reports, and the product number on the box the lamps came in. In many cases the numbers did not match up because the lamp type had been through several recent design changes, such as an upgraded version of the LED chip, which affected light output and color specifications. In some cases the catalog number was not printed on the lamp itself, or the beam spread was missing from the printing on the lamp. (Due to the emerging nature of LED technology, this is an anticipated problem with many LED products – the maintenance staff will eventually need to replace the lamp with another having the same characteristics.)

2.3.1.1 The Visual Evaluation

In most cases the LED replacement lamps were evaluated side-by-side with the halogen lamps they were to replace. The team looked at the products with an eye to aesthetic performance in addition to draft ENERGY STAR® requirements for LED replacement lamps, since the appearance of the InterContinental Hotel's interiors is so critical. Visible flicker was also noted, in the interest of reducing distracting flicker for guests and staff.

In evaluating light output, the team was aware that most of the LED lamps were not equivalent replacements for the installed halogen lamps in terms of total lumen output, center beam candlepower (CBCP), or beam spread. (LED products were still lower in absolute light quantities at that point in time). However, the hotel engineer noted that most, if not all, of the halogen lamps used in the public areas of the hotel were dimmed through the multi-floor architectural control system. Dimming lamps to this level or lower, 24/7, increases lamp life and reduces the corresponding light output, such that the LED replacement lamps might be competitive with the output of the installed dimmed halogen lamps.

2.3.1.2 LED MR16 Lamps

Nine lamps were evaluated in magnetic-transformer gimbal-ring track heads plugged into 120V light track. Six of the lamp manufacturers submitted complete data to show compliance or an attempt to comply with the lamp specification. All but three produced flicker that was considered noticeable by some team members. Light output varied considerably among samples, ranging from 36 lumens for one 4W lamp to 300 lumens for the CRS 6W lamp. One lamp appeared to deliver more light than its LM-79 report suggested, and a later check showed that the report documented a different lamp series than the sample submitted.

Figure 2.1. CRS Electronics 6W LED MR16 Lamp

The track was powered through a triac incandescent dimmer, so the team was able to observe the lamp behavior under dimming. All but the CRS lamp exhibited erratic behavior when dimmed, either dimming unevenly, shutting off below a set dimming point, or producing noticeable flicker. The CRS lamp dimmed smoothly, down to a very low level (measured at less than 10% output) before switching off, appearing to maintain color quality throughout the range.

Three lamps made it through the Round 1 evaluation and made the final cut in terms of beam spread, beam uniformity, color, intensity, and flicker. Although none of the lamps were perfect replacements to the installed halogen, all offered most of the features sought. An additional lamp was a runner-up in terms of appearance, good performance, and complete documentation, but it produced noticeable flicker. The team chose to include this one in Round 2 to get an idea of whether flicker is an issue in application.

2.3.1.3 LED AR111 Lamps

The two-story lobby space uses 75W AR111 halogen lamps because they deliver high intensity narrow beams that create visually dramatic patterns of light and shadow. Only one brand of lamps was submitted as replacements for this lamp type, a 10W LED AR111, 25° or 40° Flood distribution, warm (3000K) or neutral white (4000K) color. Participants preferred the warm color for this application, liked the color quality, but observed that the reported beam spread did not correspond to the submitted photometric report. (The actual beam spreads are 16° and 25°, respectively.) Although the intensity of light wasn't equivalent to the CBCP of the 75W AR111 halogen lamps used in the hotel lobby, the team decided to try the narrower lamp to illuminate the lobby curtains. The color is somewhat cooler than the incumbent 3000K AR111 lamps (appearing pinkish from an increased blue content), but the new interior designer on the project expressed an interest in a cooler-color light for the lobby, so that could have been an advantage.

Figure 2.2. Con-Tech 10W LED AR111 Lamp

2.3.1.4 LED PAR30 Lamps

The request for samples of this lamp type had been sent out only a week before the Round 1 evaluation, so none of the lamps had arrived by the time the team evaluation took place. PNNL provided three samples of 10W LED PAR30 shortneck lamps separately. Their performance was not equivalent to the light output of the 75W PAR30 halogen lamps installed in conference level hotel corridors, but the team thought they might work as replacements for PAR30 lamps installed in conference room emergency lighting downlights. (Two downlights per conference room operate at full output, 24/7, as emergency lighting.) Unfortunately, they did not physically fit into the downlights. The team decided to try them in Registration Desk area downlights, along with other LED PAR30 lamps when they arrived.

Figure 2.3. Philips 10W LED PAR30 Lamp

2.4 Round 2 - LED Lamp Mockup and Evaluation

2.4.1 Mockup and Meeting

Round 2 of the Evaluation was held at the InterContinental Hotel in San Francisco in February 2010, with the purpose of observing LED replacement lamps installed in areas of the hotel as a pre-test to the GATEWAY demonstration. Team members[2] wanted to feel comfortable about the lamps to which they were committing, to ensure that the LED lamps would fit the fixtures, and produce a pleasing and visually effective light.

2.4.2 Fit Test

An InterContinental Hotel facilities staff member had tried the four selected LED MR16s, thePAR30 LED, and the AR111 LED lamp in the variety of fixtures that accepted these lamps at the hotel. However, the PAR30 LED lamp was rejected because it blinked on and off continuously, upon being installed in the Registration area downlights. (This lamp was not rated for dimming and the team learned later that the circuit was dimmed at the time.) Also, one MR16 LED lamp did not light when installed into the elevator lobby monopoint luminaire, even though it did in the other MR16 fixture types. (This luminaire uses an electronic transformer with which this lamp was incompatible. Electronic transformers can cause unpredictable performance in many LED replacement lamps.)

[2] Mary Matteson Bryan, consultant to PG&E; Michael K. Souter, Luminae Souter Lighting Design; Harry Hobbs, Director of Engineering, InterContinental Hotel; Shane Caldwell and Justin Schenberg and Jedi (intern), Intercontinental Facilities Staff; Casey Neuburger, Thanke Kuhlman, Juan Laginia, and Michael Merola, Managers from the InterContinental Hotel; Erika Walther, Tyson Cook, Energy Solutions; Ku'uipo Curry, Naomi Miller, Pacific Northwest National Laboratory

2.4.3 Pre-Test of LED MR16s Replacement Lamps in Elevator Lobbies

Four models of the MR16 lamp types surviving the Fit Test were installed in four elevator lobbies, six per lobby. Members of the Evaluation team, including management representatives from the hotel, were asked to visit five successive elevator lobbies and complete a survey, blind to knowing which lamp was installed where. The incumbent halogen lamp was included in this survey. Participants did not compare notes and reactions until after the tour and survey were complete.

To summarize the results (See Appendix B for graphical results), the visually best performing lamps were the halogen MR16 incumbent lamp, the 6W CRS 26° LED MR16, and the OptiLED "Superstar" Series. The other two series lamps both produced distracting flicker (noticed independently by at least 5 participants), were too cool in appearance for the wood finishes, and produced insufficient candlepower for good signage visibility. All of these problems were likely caused by the interaction between the electronic transformers and the electronics of the LED lamps.

Some participants in the survey thought the visibility of the LEDs on the front surface of the replacement lamp was objectionable. Others thought it showed that the hotel was pushing the envelope to use LEDs, and therefore showed that the hotel was "progressive" and "cool."

2.4.4 Registration Desk Area Pre-Test

The two best lamps from the elevator lobby tests were then moved into the Registration area wall-grazing fixtures. One 11-lamp section of wall-grazer fixture was relamped with (3) CRS LED lamps, (5) 20W halogen MR16 15° incumbent lamps (GE Q20MR16/C/NSP15/CG), and a set of OptiLED Superstar LED lamps. The evaluation team preferred the color and distribution of the CRS lamp to the OptiLED lamp, so this was selected for grazing the wood walls as well as the task lighting on the desktop. The same section of fixture was then lamped with three 26° lamps and three 20° lamps, to evaluate the best beam spread for the wall grazing compared to the narrow spot halogen lamp. The visual effect was judged acceptable for both beam spreads, even though they lighted the top of the wall more brightly than the base of the wall. The team decided to use the same 26° beam spread selected for both the elevator lobbies and the Registration Desk task lighting because this reduces the number of lamps the Hotel must keep in stock and potential confusion for the maintenance staff.

This test on the wood was done with the control zone dimmed to "80" on the multi-floor architectural control system. When the dimming setting was reduced to "50", the halogen lamps dimmed as expected, but the CRS MR16 LED lamps dimmed only slightly and oscillated in output. This oscillation stopped when the setting was raised to "75", but the light output did not appear to change much. (After watching the lamps dim smoothly on the magnetic transformer track heads in January, the team wondered if the remote transformers for the wall grazer were electronic. Indeed, this proved to be the case.)

Four newly-arrived Philips 11W LED PAR30 Short-neck 25° 3000K lamps were installed in the Registration area fixed downlights in front of the desk. Although the intensity and beam spread was acceptable, the beam color was too cool compared to light from the grazed wood wall. The team decided to order this lamp in 2700K color for the final demonstration.

2.4.5 Pre-Test of AR111 Lamps in Lobby Lounge

A single 10W AR111 nominal 25° (actual 16°) LED lamp was installed in the 20’ tall ceiling to produce a splash of light on the gray sheer curtains. The team was impressed with the intensity of the light beam in application, and liked the color quality and lack of perceptible flicker. However, the light was cooler (pinker) than the halogen it replaced and shifted the color emphasis in the space from gold to silver. Other fixtures in the center of the room used higher wattage halogen AR111s that could not be matched in intensity by this LED lamp. To avoid mismatched lamp colors in this lobby, this area was eliminated from the final demonstration.

2.4.6 Conclusions from Round 2 Testing

Except in the wall-grazing application, the installed MR16 LED and PAR30 LED replacement lamps did not match the undimmed halogen incumbent lamps in terms of candlepower, light output or color quality. However, several of the LED test lamps looked good enough to consider them for their potential energy savings, especially in areas where halogen lamps are normally dimmed. At the time of this demonstration, the best of the MR16 LED lamps were roughly equivalent to 20W halogen MR16s. They performed well enough in lower ceiling spaces although they did not have sufficient intensity (candelas) to make the InterContinental Hotel’s surfaces and signs visible when the ceiling heights were greater than 9’. So, the final areas selected for the GATEWAY demonstration were the following lower-height spaces:

- Elevator lobby accent lighting using CRS MR16 LED 26° lamp on Floors 1, 7, 8 (18 lamps total)
- 7th and 8th Floor Guest Room corridor accent lights using CRS MR16 LED 26° lamps (12 lamps total)
- Registration Desk area including wall grazing with CRS MR16 LED 26° lamp (217 total), desk task lighting with same lamp (7 total), and Philips EnduraLED PAR30 2700K 25° lamps in recessed downlights (6 lamps total)
- 4th Floor conference rooms (404, 405, 406, 407, 408, 409) PAR30 downlights on emergency power (and therefore continuous operation) with Philips 11W Shortneck PAR30 EnduraLED 25° lamps (12 lamps total). These were equipped with a 1” long socket extender because the luminaire requires a longer neck lamp for proper fit.

(Note: The OptiLED “Superstar” LED MR16 lamps survived the Round 2 tests and were planned to be demonstrated in the 1st, 7th, and 8th Floor Elevator Lobbies as well as 7th and 8th Floor Guest Corridors. Six test lamps were left in place in the 1st Floor Elevator Lobby after the Round 2 meeting, and within a couple of days the hotel called to say they had been removed because the lamps were flickering. The OptiLED lamps were consequently eliminated from the final demonstration plans. Later investigation revealed that the architectural dimming system had reverted to its normal dimming programming after the evaluation team meeting, reducing the voltage to the lamps, and making them unstable. They were incorrectly identified as poor performers because no one was aware of the dimming situation until several weeks later.)

2.5 Final Demonstration "Before" and "After" Installation

One more issue arose after PG&E ordered the lamps for the final installation. The supplier of LED chips for CRS's MR16 lamps changed its binning specifications. The resulting lamp color had a slightly pinker appearance, but ironically dropped in measured CCT. Three samples were immediately shipped to PNNL, the Lighting Designer, and the hotel for a further review of acceptability before 200+ lamps were ordered. Fortunately, the color was preferred, so the order proceeded.

2.5.1 "Before" Conditions

All hotel test areas were relamped with new Philips MR16 and PAR30 halogen lamps, and the Lighting Designer checked for proper aiming of the adjustable lighting. The hotel staff was surveyed for their responses. A week later on April 21, 2010, PNNL directed photography and took measurements using a Minolta TL-1 illuminance meter. Note that the normal dimming settings of the architectural dimming system were unchanged for this work.

2.5.2 "After" Conditions

Overnight the halogen lamps were replaced by the hotel facilities staff with the new MR16 and PAR30 LED replacement lamps, of which eight of each type had been photometered and labeled to document baseline performance, and the dimming settings for the demonstration areas changed to 100% output. The next day, the hotel staff and lighting designer's response to the relighted areas was enthusiastic.

At 6pm another hiccup occurred. The PAR30 LED lamps in the Registration Desk area began to flash every couple seconds in an alarming way. Once again, the dimming system had unexpectedly reverted to its original dimmed programming at its regular evening time signal, and the first floor lighting circuits were all receiving a very low voltage. Once this was corrected, and the dimming level of all scenes was permanently raised to "100", the PAR30 lamps behaved normally.

Photography was repeated with the new lighting, and illuminance measurements were repeated. The staff members were surveyed for their reactions, the Lighting Designer was queried for his response, as well as several other members of the Evaluation Team.

2.5.3 Photographs

The next several pages display the changes to the hotel lighting using before and after photographs of various locations within the building. The professional photographer, Kenneth Rice Photography, took care to use similar camera settings for both conditions so that the photos are comparable and so that they represent the way the spaces looked to the observer.

Higher illumination levels and improved uniformity are among the benefits immediately visible from the LED products on the first floor (Registration Desk Area and Elevator Lobby), when compared to the halogen lighting that had been routinely dimmed to very low levels.

Figure 2.5. 1st Floor Elevator Lobby - Halogen Lamping (Dimmed). **www.kenricephoto.com**

Figure 2.4. Closeup of elevator signage (Halogen). **www.kenricephoto.com**

Figure 2.6. Closeup of monopoint accent light. **www.kenricephoto.com**

Figure 2.7. 1st Floor Elevator Lobby - LED Lamping (Undimmed). **www.kenricephoto.com**

Figure 2.8. Closeup of elevator signage (LED). **www.kenricephoto.com**

Figure 2.9. Conference room lighting with halogen downlights at far end.
www.kenricephoto.com

Figure 2.10. Conference room emergency lighting only – Halogen.
www.kenricephoto.com

Figure 2.11. Closeup of recessed PAR30 downlight in Conference Room.
www.kenricephoto.com

Figure 2.12. Conference room emergency lighting only – LED.
www.kenricephoto.com

Figure 2.13. Conference room lighting with LED downlights at far end.
www.kenricephoto.com

Figure 2.14. 8th Floor Elevator Lobby - Halogen Lamping.
www.kenricephoto.com

Figure 2.15. Closeup of elevator signage (Halogen).
www.kenricephoto.com

Figure 2.17. Closeup of monopoint accent light.
www.kenricephoto.com

Figure 2.18. 8th Floor Elevator Lobby - LED Lamping.
www.kenricephoto.com

Figure 2.16. Closeup of elevator signage (LED).
www.kenricephoto.com

Figure 2.19. Guest Corridor Artwork Lighting (Halogen). **www.kenricephoto.com**

Figure 2.20. Closeup of guest corridor artwork (Halogen). **www.kenricephoto.com**

Figure 2.21. Closeup of monopoint accent light. **www.kenricephoto.com**

Figure 2.22. Guest Corridor Artwork Lighting (LED). **www.kenricephoto.com**

Figure 2.23. Closeup of guest corridor artwork (LED). **www.kenricephoto.com**

Figure 2.24. Registration Desk area with halogen accent and wall-grazing (onyx panels are backlighted with fluorescent lamps, and the pedestal lights use incandescent lamps). **www.kenricephoto.com**

Figure 2.25. Registration Desk area with LED accent and wall-grazing (onyx panels are backlighted with fluorescent lamps, and the pedestal lights use incandescent lamps). **www.kenricephoto.com**

Figure 2.26. Registration Desk area counter showing overhead halogen accent lights**. www.kenricephoto.com**

Figure 2.27. Closeup of wall grazing lighting (LED). **www.kenricephoto.com**

Figure 2.29. Registration Desk area counter showing overhead accent lights with LED replacement lamps. **www.kenricephoto.com**

Figure 2.28. Closeup of wall grazing lighting (Halogen). **www.kenricephoto.com**

2.6 The Control System and its Effect on LED Replacement Lamps

The InterContinental Hotel public areas on Floors 1-6 are controlled by a multi-floor architectural dimming system. The first floor lobby area has two "scenes", triggered at 6am and 30 minutes before sunset, as detailed in Table 2.1 below,

Table 2.1. Dimming Settings

Space/Application	Lamp Type	Daytime Setpoint	Nighttime Setpoint
Registration desk area wall grazing	MR16	80	50
Registration desk area counter downlights	MR16	70	50
Registration desk area downlights for floor	PAR30	100	35
1st Floor elevator lobby accent lights	MR16	80	80
Guest floor 7 – 9 elevator lobby and corridor accent lights	MR16	100	100
Emergency circuit downlights in conference rooms	PAR30	100	100

The numerical dimming setting on the multi-floor architectural control system refers to an approximate *perceived* dimming level, or the apparent percentage of rated light output at full power. This percentage is roughly equivalent to the percent of full rated wattage drawn when operated in this dimmed mode, but this percentage does not reflect the actual impact of dimming on *measured* light output. The measured percent of rated light output from a dimmed incandescent lamp is approximately the square of the % rated wattage.[1] For instance, a dimming setpoint of "70%" indicates approximately 70% of full wattage and an apparent reduction to roughly 70% of full light output, but actual measured light would be at approximately 49% of full output. (Note that these values are intended for incandescent lamps and may not apply to halogen lamps, although in absence of more definitive data, GATEWAY is using this as a first approximation. See IESNA Lighting Handbook, 9th Edition, pp. 6-13 and 6-14.) Additionally, these already approximate values are further complicated by a low-end trim of 5% (maximum dimming) and a high-end trim of 90% (minimum dimming) for this particular system. As a result, a dimming setpoint of "100" does not provide full rated light output. Furthermore, when the dimming level is less than 90% of rated voltage, filament evaporation no longer determines halogen lamp life. Combinations of other field factors such as shock, vibration, and temperature dominate the mode of failure. For this reason, GATEWAY uses a maximum life multiplier of 3, which is more consistent with the hotel's anecdotal relamping history. GATEWAY assumptions for dimming effects on wattage, light output, and rated lifetime are summarized in Table 2.2 below.

Table 2.2. Assumed Operating Characteristics of Dimmed Halogen Lamps

Dimming Setpoint	Percent of Rated (Full Output) Value			
	Perceived Output	Measured Output	Input Wattage	% Rated Life
0	5	0	5	300
35	35	12	35	300
50	48	23	48	300
70	65	42	65	300
80	73	53	73	300
100	90	81	90	225

[1] See the 9th Edition IESNA Lighting Handbook, page 6-13, 6-14, and Figures 6-19 and 27-4.

When the six sample CRS LED MR16 lamps were originally evaluated in the wall grazing fixtures of the Registration Desk area along with halogen MR16 lamps in all other sockets, the CRS lamps dimmed down to about "50" before beginning to flicker. When the wall grazing was completely retrofitted with LED lamps, this significantly reduced the load on the remote electronic transformers. As a consequence of the interaction among the dimmer type, the transformer type, and the LED lamp's built-in driver, the LED lamps produced no noticeable reduction in output when the dimming level was reduced. However, as soon as the dimming system setting was reduced below "75", the CRS MR16 lamps began to flicker.

The Philips PAR30 LED lamps in downlights in the Registration Desk area did not appear to drop in output when the dimming setting was reduced, so the setting was fixed at "100". As described earlier, there was a confusing moment when these prominently-located lamps suddenly began to strobe with fire-alarm-type flashes the evening of the installation. The timeclock built into the dimming system had automatically switched to its original setting of "35" for this control group. As soon as the setting was re-set to "100", the lamps behaved normally. (The operation of the sophisticated dimming system was still unfamiliar to the hotel facilities staff, especially when it came to making permanent changes to the dimming system settings.)

To avoid flicker, strobing, and other unstable behavior, the final dimming setting was set at "100" for all control circuits with LED lamps, even in the evening when less light would have been preferred.

Dimming of LED products is a challenge for manufacturers of dimming systems, LED drivers, and transformers/power supplies. Although the LED chips themselves are fully dimmable, their drivers and power supplies may not be compatible with traditional phase-cutting dimming circuits. For reliable dimming, the LED product must be carefully coordinated (and tested) with

- the dimmer type (i.e. triac, magnetic low-voltage, reverse phase control, pulse-width-modulation, etc.)
- the LED driver, whether integral to the lamp or remote
- any other power devices on the circuit, such as a transformer or other lamps or luminaires
- the loading on the transformer, if applicable.

3.0 Before and After Illuminance Measurements

Halogen lamps in the "before" condition of the registration desk and 1st floor elevator lobby areas were dimmed from "35" (PAR30 lamps) to "65", "75", or "80" (MR16 lamps), so measured light output is expected to range from roughly 10 to 65% of rated light output. (Reference: 9th Edition IES Lighting Handbook, Figure 27-4, Square Law Curve. Also see Footnote 4.) Table 3.1 below summarizes the illuminance values measured with the same Minolta TL-1 meter for both the halogen "Before" and LED "after" conditions.

Table 3.1. Illuminance Measurements and Estimated Wattages for First Floor

Area	Meter height (above finished floor) and orientation	Halogen "Before"		LED "After"	
		Avg. illum. (fc)	Approx. input power (W)	Avg. illum. (fc)	Approx. input power (W)
Registration Desk Area - wall grazing	7' vert.	5.2	2929.5	34.3	1302
	5' vert.	3.5	2929.5	22.5	1302
	3' vert.	3.0	2929.5	17.6	1302
	0' horiz.	10.7	2929.5	81.9	1302
Registration Desk Area - Counter Lighting	3' horiz.	9.5	126	17.5	42
Registration Desk Area - Floor Lighting	0' horiz.	1.5	393.8	18.3	66
1st Floor Elevator Lobby Accent Lighting on Signs (Illuminance includes ambient lighting from fluorescent luminaires)	5' vert. Center of beam	7.2	144	26.3	36

The 7th and 8th floor elevator lobbies and guest floor corridor lighting had no dimming control, so the halogen lamps were delivering full output when the measurements were taken, as were the emergency-circuit downlights in the Conference Rooms. Table 3.2 below summarizes the illuminance values measured with the Minolta TL-1 meter for both the halogen "Before" and LED "after" conditions.

Table 3.2. Illuminance Measurements and Estimated Wattages for Upper Floors

Area	Meter height (above finished floor) and orientation	Halogen "Before"		LED "After"	
		Avg. illum. (fc)	Approx. input power (W)	Avg. illum. (fc)	Approx. input power (W)
4th Floor Conference Room – Floor Illum's Beneath Downlights on Emergency Ckt.	0' horiz.	12.6	150	10.0	20
8th Floor Elevator Lobby (includes ambient lighting)	5' vert. Ctr. of beam	63.5	180	29.2	36
	5' vert. Ambient on wall	6.1	180	6.6	36
8th Floor Guest Room Corridor Accent Lighting on Artwork (Illuminance includes ambient lighting)	4' to 7' vert. on framed photo	37.8	90	24.6	18

4.0 Feedback - Survey and Interview Results

The GATEWAY program considers user feedback on the qualitative aspects of LED lighting to be an essential component of the overall evaluation. Products that fail to maintain or improve the visual appearance of the target space relative to the incumbent technology are likely to encounter significant resistance to their use, and are therefore not likely to be adopted on a wide scale regardless of the energy savings they offer. In addition, quantitative analysis does not reveal the full benefit of the change; it does not capture dramatic lighting effects that contribute to visual interest, and disregards other aspects impacting human perception such as glare and color quality of skin tones and exquisite fabrics and finishes, dramatic light effects that contribute to visual interest, control of light that eliminates glare, and other aspects impacting human perception.

Below are comments and responses from people with important economic, environmental, maintenance, design, or other perspectives regarding the relighted areas.

Staff: Employees who work at or around the Registration Desk of the InterContinental Hotel were asked to complete surveys regarding the lighting before the changeout, and again after the change. (See Appendix C) 13 surveys were completed, and the LED lamping received equivalent or better scores than the halogen in all but the question on warmness or coolness of the light (Question 10 – They thought the LED lighting slightly too warm). Most of the questions where the halogen lamping scored poorly regarded light levels and the ease of reading or seeing colors (Questions 2, 6, 8, 10). It is not surprising that the halogen solution seemed dim and less conducive for reading or seeing colors, since the lamps were operating at very low dimming levels. This in turn positively affected the overall favorability of the LED system, since the higher light levels from the undimmed LED lamping made it easier to see faces of customers as well as the keyboards and paperwork. Because there were such different conditions, caution should be used in comparing the "Before" and "After" responses.

Owners: Upon visiting the hotel a few weeks after the LED retrofit, Mrs. Lundquist remarked that she liked the lighted appearance better than the original halogen system**.** John Buss, an owner and one of the original evaluation team commented:

> "I was impressed by the changes and, unhesitatingly, confirm that the lamping changes have in no way detracted from the original lighting design intent. On the contrary, the front desk area has been enhanced and the millwork, in particular, registers richer tones. I was also viewing the front desk area at night last Saturday evening and do not feel that it is too bright although I can understand that some might wish it to be dimmed a little. I understand that Michael Souter is investigating this possibility. I look forward to reviewing further lamping changes and am greatly impressed by the results so far."

Management: Juan Laginia, Director of the Front Office said,

> "After a couple of weeks with the new lighting I was wondering how we were able to "survive" without it before. Besides the fact it enhances the marble, the wood panels and the art work in the lobby, our agents can work better now. Even the guest experience is enhanced. I think from many different points of view this is a great change, where instead of investing more money to improve the space we are saving money while being gentle to our mother earth."

Payman Noroozi, Night Manager, commented,

> "I think the lighting in our lobby is excellent. The guests are more visible and at night that is very important. Also I think the lobby is more visible from the outside of the hotel and the hotel security cameras. I like the new lights and the fact that we are saving money on our energy every month.

Lighting Designer: Michael K. Souter, original lighting designer on the hotel, had this to say.

> "In general, I was a bit uncertain that the LED retrofit would work for various reasons. One reason was because of the sketchy products on the market and their lack of standardization. This could lead to possible lack of compatibility with the existing transformers and control systems and have a negative affect on the LED's performance. Some of these suspicions proved correct during the testing process when we saw flickering and dimming problems with some of the candidates. This was a very crucial part of the process.
>
> Another concern was the overall performance of the LED lamps in comparison with the installed MR16 lamps in light intensity, color temperature and color rendering. However, after the swap was made, I was very impressed with the quality of the lighting on the artwork, the color rendering of the wood paneling and the light intensity during the day. My only remaining concern is if the light level might be too bright at night in the reception area and the inability to dim them if necessary with the existing control system. I am puzzled as to why the winning candidate dimmed well during the testing process but won't dim on the hotel control system. It might be worth investigating if [the dimming manufacturer] has an interface module that would help.
>
> In general I am very pleased with results to this point and hope that over time the lighting will continue to perform well. Also, I look forward to the time when all of the AR111 halogen lamps can be retrofitted. Presently there are no candidates available."

Facilities Staff: Harry Hobbs, Director of Engineering, and the facilities staff expressed satisfaction that the LED lamp life will reduce the time and expense of maintaining light bulbs in the hotel. Once the installation was complete, they were eagerly looking for other hotel areas that could easily be retrofitted with the same LED lamps.

Director of Security: After the LED lamps were installed in the Registration Desk area, increasing light levels compared to the original dimmed halogen installation, Michael Merola said "I can assure you that the increase in the lighting level has made a very positive impact on the security camera images."

5.0 Economics

5.1 Life Cycle Cost Analysis

LED retrofit lamps' higher upfront costs are theoretically offset by reduced electricity costs and maintenance costs over the life of the LED lamps. The LED integral replacement lamps used in this retrofit project will be operated 24 hours a day, 365 days a year, have a warranty duration of 3 years, and a claimed useful (L_{70}) life of 45,000 to 50,000 hours, or about 5.5 years. This economic analysis uses the National Institute of Standards and Technology's Building Life-Cycle Cost (BLCC) software.[1] This software calculates the life-cycle costs for energy conservation projects that have significant upfront costs, but save energy over the long term. This software was used to model the present value life-cycle cost of the 263 CRS LED 6W MR16 lamps and 24 Philips EnduraLED 11W PAR30 lamps installed as part of the GATEWAY project in comparison to the life-cycle costs of the previous halogen lighting. Both the base-case and LED scenarios are based on a 3-year analysis of each system's respective costs. This retrofit project is evaluated in terms of estimated retrofit costs (including labor), projected 3-year energy costs, taking into account projected real fluctuations in energy prices and 3-year maintenance costs. Full detailed reports can be found in Appendices D-1, D-2, and E.

In the US, commercial electricity prices vary greatly from state to state and region to region. As a reference point, the U.S. Energy Information Administration publishes the Average Retail Price of Electricity to Ultimate Customers by End-Use Sector by State.[2] The national average retail price of electricity to ultimate commercial customers in October 2009 was approximately $0.10/kWh, and commercial electricity prices ranged from a high of $0.24/kWh in the state of Hawaii, to a low of $0.07/kWh in Missouri. The average commercial price of electricity in California is $0.12/kWh, slightly higher than the national average. However, the Intercontinental Hotel opts to pay a "green energy" premium above their typical commercial energy rates to purchase carbon offset and thereby pays about $0.13/kWh for electricity. In general, LEDs are more likely to be economically viable in places where electricity costs are high enough that the energy savings they generate contribute significantly to paying back the high initial cost of LED products.

In addition, LED products have been found to be most cost-effective in installations where maintenance costs are high enough that they help to off-set the high initial cost of LEDs. At the InterContinental Hotel, most lighting-related maintenance takes place overnight, and spot relamping is estimated to cost $50 per burned-out bulb. The halogen lamps being used at the InterContinental have lifetimes of 3,000-5,000 hours, although GATEWAY estimated this was extended 3 times in the Registration Desk and 1st Floor Elevator areas because of dimming. As the lights in common areas of the hotel are on 24 hours a day, 365 days a year, these light bulbs burn out quickly and the hotel's lighting requires constant maintenance. In general, sites with higher relative maintenance costs will benefit more from the LED's longer life and consequent reduced maintenance costs.

BLCC comparisons are based on retail lamp prices provided by the manufacturers, their representatives, or found online. The CRS LED MR16 lamps cost $65 each, replacing halogen MR16s that cost $8 each. The 11-watt Philips EnduraLED PAR30 lamps cost $60each, replacing halogen PAR30s that cost about $14 each. The initial retrofit was completed in one night, so the per-lamp group relamping labor cost was $3 each. The initial LED lamp retrofit cost including labor is $19,396.

[1] Available online at http://www1.eere.energy.gov/femp/information/download_blcc.html
[2] Available online at: http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

The halogen lamp replacement cost is $2075 per year. At $50 per lamp in labor, the halogen lighting system costs about $10,291 annually, for a combined lamp and labor cost of $12,366. While the LED lamps are not expected to require any maintenance or to fail in the first 3 years, to build a reasonably conservative scenario, the BLCC comparison assumes that 10% of the LED lamps will need to be replaced annually. As these light bulbs are covered by a 3 year warranty, there would be no cost for the replacement lamps; however, the $50 per lamp labor cost to swap out failed LED lamps would total $1,435 per year.

5.2 Payback Horizons and Economic Feasibility

Table 5.1, below, summarizes the input data and Life-Cycle-Cost analysis for the halogen and the LED lighting systems.

Table 5.1. InterContinental Hotel SF Life Cycle Cost Analysis (Including Labor) – Input Data and Summary

	Halogen System	LED System
Initial Capital Costs for all components	$0	$19,396
Average Annual Electrical Energy Usage	51,975.27 kWh	16,135.9 kWh
Average Electricity Cost per kWh	$0.13	$0.13
First Year Energy Consumption Cost	$6,757	$2,098
Study Period	3 years	3 years
Discount Rate	7.30%	7.30%[3]
Discounting Convention	End-of-year	End-of-year
Present Value (PV), Energy Consumption Costs	$16,593	$5,151
Annual Value, Energy Consumption Costs	$6,361	$1,975
Present Value, Relamping and Lamp Cost	$32,399	$3,746
Annual Value, Relamping and Lamp Cost	$12,420	$1,436
Present Value, Total Life-Cycle Cost	$48,992	$28,294
Annual Value, Total Life-Cycle Cost	$18,782	$10,847
Total Annual Emissions		
CO_2	27,949.37 kg	8676.99 kg
SO_2	6.69 kg	2.08 kg
NOx	22.66 kg	7.03 kg
Comparative PV Data over 3 year study period		
Net Energy Savings from LED Lamping		$11,442
Net Savings from LED Lamping		$20,698
Savings-to-Investment Ratio		2.20
Adjusted Internal Rate of Return		39.67%
Estimated Simple Payback occurs in year		2
Life-Cycle Electrical Energy Savings		107,444.5 kWh
Life-Cycle CO2 Emissions Reduction		57,777.58 kg
Life-Cycle SO2 Emissions Reduction		13.83 kg
Life-Cycle NOx Emissions Reduction		46.83 kg

[3] Discount rate estimated by PNNL economist for the building sector, and confirmed by hotel.

The GATEWAY demonstration replaced 287 lamps drawing a total of 5.933 kW in three specific areas of the hotel: The reception area, the guest elevator lobbies, and the conference room emergency downlights. All of these fixtures are operated 24 hours a day, 365 days a year. Total estimated annual energy use of the halogen system was 51,975 kWh. The LED retrofit required an initial investment, versus the halogen lights, which were already installed. Lamp life was assumed to be 25,000 hours for the LED lamps, with 10% of the lamps replaced per year for a replacement lamp labor cost of $1436 annually. Over 3 years, the LED lights will save the InterContinental Hotel $11,442 in total energy costs, and reduce their energy consumption by 107,444.5 kWh. The halogen system, on the other hand, will require a continued total investment of $2,210 annually in halogen replacement lamp costs.

Excluding the cost of relamping labor, over 3 years, the halogen system will have a total life-cycle cost of $18,803. As a result of the LED system's high upfront costs, the LED lights would have a total life-cycle cost (without relamping labor) of $24,548, and so would actually cost more than the halogen lighting. If labor were not included in the calculation, the LED replacement lamp energy savings would not repay the initial investment until the 6th year of operation.

However, when labor costs are factored in, this changes dramatically. The halogen lamps, as a result of their short lifetimes, have a present value cost of $32,399 for replacement lamps and labor, while the same LED cost is $3,746. This translates to a Present Value cost of $48,992 over the 3-year life cycle for the halogen system, and $28,294 for the LED system. The difference is $20,698 in energy, maintenance, and replacement costs over 3 years, or a 1.1 year simple payback on the initial investment. The LED lamps' lower energy cost and lower maintenance cost help to offset their high initial cost.

There are many factors to take into account in determining whether an LED system is cost-effective for a given site. This report focuses only on the initial investment, energy, and maintenance costs. In general, an LED lighting system can be cost effective when electric utility rates are higher than average, hours of operation are long, and labor costs for relamping are high. In addition, LED systems will have shorter payback periods as the technology becomes less expensive.

6.0 Lessons Learned

6.1 Don’t Buy LED Replacement Lamps Sight Unseen

Qualitative and quantitative characteristics of LED products vary widely. Allocate time and expertise to see, handle, mock up, and test potential replacement lamps in the specific luminaires and spaces before committing to large retrofit projects.

6.2 Color

LED MR-16 replacement lamps are now available with a spectral power distribution that is extremely close to the incumbent halogen lamps in its color appearance and color rendering properties. Look for lamps with a Correlated Color Temperature (CCT) of 2700 to 3000K, and Color Rendering Index (CRI) value greater than 80 with an R9 value >50, or Color Quality Scale (CQS) value greater than 85. Look closely at color appearance of important objects and finishes in the space with the selected lamps. Your eyes are more reliable than color metrics alone.

6.3 Test in Place

Test color acceptability, flicker, size and characteristics of the emitted beam of light, as well as compatibility with installed transformers and dimmers. (In many MR16 luminaires, a magnetic transformer may be compatible with more LED replacement lamps than an electronic transformer.) Get a 3 to 5-year warranty on life, light output, and color characteristics. Local electric utilities and ENERGY STAR® specifications may provide additional guidance on product selection.

6.4 LEDs can be Economically Viable

Good-quality LED replacement lamps can be economically viable in spite of their high initial cost. Consider them when:

- Electric rates are higher than average (e.g., greater than $0.11/kWh melded rate)
- Labor costs for relamping are high because of hard-to-reach locations, areas where skilled labor is costly, the need for access outside of normal work crew hours, access to the space is limited because of special security clearance, clean room requirements, etc.
- Hours of operation are extensive (e.g., greater than 40 hours per week).
- Utility rebates or incentives are available.

6.5 Expect Lower Light Output

LED replacement lamp products are improving in light output rapidly. At the time of this project, however, they were only able to replace lower wattage PAR30 and MR16 halogen lamps. If lower light levels are acceptable, then these lamps are candidates for retrofit projects. Similarly, if the existing halogen lamps are dimmed in use, the LED replacement lamp light output may be equivalent when operated at full power. Or, if the room or installation was over-lighted with halogen lamps, LED replacements may correct for over-lighting.

At this point in time, the LED replacement lamps are more suitable for low-ceiling applications, low light level applications, and accent lighting applications than for general lighting. This is because the light output is generally lower and the beam sizes tend to be narrower than the halogen “Flood” lamps used for general lighting.

6.6 Know Your Dimming System

Many of the unexpected turns in the process of selecting and testing LED replacement lamps were due to unfamiliarity with the whole-building dimming system. Halogen lamps on the lobby floor were operating in a very low dimmed state, which made it difficult for the staff to see to do their work. The facilities staff did not feel empowered to make dimming level changes, and it was not immediately obvious how to make dimming level changes permanent.

6.7 To Dim or Not to Dim

Dimming of LED replacement lamps adds complexity to an installation. Some LED lamps flicker when dimmed; others don’t dim smoothly or don’t dim to an acceptably low level. Some lamps dim well on a magnetic transformer but not on electronic; some lamps dim smoothly in all situations. A product cut sheet may suggest dimmability, but it is important to test a specific lamp or group of lamps with the circuit’s loading, transformer, and dimmer type. Instability of operation may indicate that lamp type, loading, transformer type, or dimmer type may need to be changed.

The National Electrical Manufacturers Association (NEMA) recognizes the complexity of dimming LED systems.To stay abreast of LED product dimming issues, and potential protocols, and standards, see the National Electrical Manufacturers Association (NEMA) website (www.nema.org). Some dimmer manufacturers are testing their products for compatibility with a variety of LED products and posting the results online. Contact your dimming product manufacturer for this information.

Appendix A

Lamp Procurement – LED Replacement Lamps

Appendix A – Lamp Procurement – LED Replacement Lamps

Target Performance Specifications

- 35W AR111 25° Narrow Flood (12V)
- 20W MR16 10° Narrow Spot (12V)
- 75W PAR30 40° Flood (SHORTNECK) (120V)

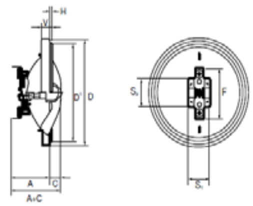
A.1 LED Replacement for Halogen AR111 12V 35W 25° Flood Lamp Specification

A.1.1 Overview

The DOE GATEWAY program's three stated goals are to field test SSL technology that: matches or improves the quality of existing lighting, reduces overall energy consumption and is cost effective for the end user. This GATEWAY Demonstration project will study the applicability of using commercially available light-emitting diode (LED) lamps as replacements for halogen lamps. Participants in this demonstration project include a high-end hotel in San Francisco, LED lighting manufacturers, Lighting Designers, Interior Designers, PG&E and the Pacific Northwest National Laboratory (PNNL). LED lamps used in this project will be installed in three common areas of the hotel test site to replace the current high CRI Halogen lamps. These LED lamps will need to satisfy the quality requirements of the hotel guests, the hotel owners, management, employees, as well as the lighting designers, interior designers, electrical utility and researchers involved in this project. The LED lamps will be evaluated in terms of qualitative aspects as well as their energy efficiency and cost-effectiveness. Replacement lamps will not be dimmed, but must be compatible with the existing fixtures and dimming system. They must reduce energy consumption and lower the life-cycle costs of the hotel's existing lighting system. This project is supported under the U.S. Department of Energy (DOE) Solid-State Lighting Program. PNNL manages GATEWAY demonstrations for DOE and represents their perspective in the conduct of the work. PG&E and PNNL will conduct in situ measurements and analysis of the results. Quantitative and qualitative measurements of light and electrical power will be taken at the site for both Halogen and LED light sources. Lamps selected for this project will be installed at the site in March 2010 and periodically assessed until 2012.

A.1.2 Time Line

Request for lamp submissions and documentation will be released Friday, January 9, 2010. Manufacturers who would like to participate must submit three (3) lamps plus documentation for testing and review by January 20, 2010. Only lamps that are currently available in needed quantities and deliverable by March 15th, 2010 will be considered for this project. The candidate lamps submitted will be tested and visually evaluated, and final selections of lamps for this demonstration project will be based on best overall match to the needs of the project. Lamps should strive to meet the Energy Star Integral Lamp Specification (http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf). Lamp selections will be made by February 1, 2010 and the lamp manufacturer/supplier will be notified. Lamps will be installed in the hotel during the third week of March. If you would like to be considered as a partner in this demonstration, please send the lamp samples and performance documentation to: Thor E. Scordelis, Sr. Program Manager Pacific Gas & Electric Company, 245 Market Street, Room 395B San Francisco, CA 94105 (415) 973-6184.



	AR111	mm	inch
Overall length	A + C	60	2.36
Projection of grip cap	C	15±0.5	0.59+0.02
Length w/o grip cap	A	45±0.4	1.77+0.02
Reflector diameter	D	111-0.2	4.37-0.01
	D_1	102.5 ±0.3	4.04+0.01
Thickness of refl. edge	V	9.5+0.5	0.37+0.02
	H	2.5-0.7	0.98-0.03
Dim. of ceramic holder	S_1xS_2	25 x 32	9.84 x 1.26
Distance of contact strips	F	53.2 ± 1	2.09+0.04

General Description: LED AR111 12V 25° Flood replacement lamp

Lamp Type: AR111

Replacement for: Halogen 35 watt or higher

Voltage: 12V AC

Power factor ≥ 0.70

Minimum Luminous Efficacy: 45 lm/W

Base: G53 screw terminal base

Physical Fit: Equal to standard AR111 Halogen incumbent lamp, replacement lamp must fit into RSA Combolight Recessed Low-Voltage AR111 Trimless Standard Fixture

Beam angle at 50% of Maximum intensity (deg): 25°

Target CBCP (cd): 2500

Minimum Lumen Output ≥350 lumens

Minimum Life expectancy: 25,000 hours

Lumen Maintenance: ≥ 70% lumen maintenance (L70) at 25,000 hours of operation

Target CCT: 3000K ± 200K

Duv: 0.000±0.003

Chromaticity Maintenance: change of chromaticity within 0.007 on the CIE 1976(u'v') diagram over the minimum lumen maintenance test period of 6,000 hours

Color Rendering:

1. Color Rendering Index (CRI)≥80 and R9≥50

   OR

2. Color Quality Scale (CQS) ≥85

Flicker: No perceptible flicker

Warranty Terms: a warranty must be provided for lamps covering material repair or replacement for a minimum of three years (3) from date of purchase

Dimming: Lamps may be dimmable or non-dimmable. Lamps used in this demonstration will not be dimmed, but lamps will be operated on a multi-floor architectural dimming system

Documentation Requested: Copies of LM-79 Test reports done at a DOE CALiPER-Recognized or NVLAP-Accredited testing facility

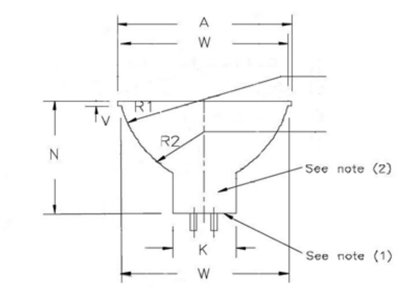
A.2 LED Replacement for Halogen MR16 12V 20W 10° NSP Lamp Specification

A.2.1 Overview

The DOE GATEWAY program's three stated goals are to field test SSL technology that: matches or improves the quality of existing lighting, reduces overall energy consumption and is cost effective for the end user. This GATEWAY Demonstration project will study the applicability of using commercially available light-emitting diode (LED) lamps as replacements for halogen lamps. Participants in this demonstration project include a high-end hotel in San Francisco, LED lighting manufacturers, Lighting Designers, Interior Designers, PG&E and the Pacific Northwest National Laboratory (PNNL). LED lamps used in this project will be installed in three common areas of the hotel test site to replace the current high CRI Halogen lamps. These LED lamps will need to satisfy the quality requirements of the hotel guests, the hotel owners, management, employees, as well as the lighting designers, interior designers, electrical utility and researchers involved in this project. The LED lamps will be evaluated in terms of qualitative aspects as well as their energy efficiency and cost-effectiveness. Replacement lamps will not be dimmed, but must be compatible with the existing fixtures and dimming system. They must reduce energy consumption and lower the life-cycle costs of the hotel's existing lighting system. This project is supported under the U.S. Department of Energy (DOE) Solid-State Lighting Program. PNNL manages GATEWAY demonstrations for DOE and represents their perspective in the conduct of the work. PG&E and PNNL will conduct in situ measurements and analysis of the results. Quantitative and qualitative measurements of light and electrical power will be taken at the site for both Halogen and LED light sources. Lamps selected for this project will be installed at the site in March 2010 and periodically assessed until 2012.

A.2.2 Time Line

Request for lamp submissions and documentation will be released Friday, January 9, 2010. Manufacturers who would like to participate must submit three (3) lamps plus documentation for testing and review by January 20, 2010. Only lamps that are currently available in needed quantities and deliverable by March 15th, 2010 will be considered for this project. The candidate lamps submitted will be tested and visually evaluated, and final selections of lamps for this demonstration project will be based on best overall match to the needs of the project. Lamps should strive to meet the Energy Star Integral Lamp Specification (http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf). Lamp selections will be made by February 1, 2010 and the lamp manufacturer/supplier will be notified. Lamps will be installed in the hotel during the third week of March. If you would like to be considered as a partner in this demonstration, please send the lamp samples and performance documentation to: Thor E. Scordelis, Sr. Program Manager Pacific Gas & Electric Company, 245 Market Street, Room 395B San Francisco, CA 94105 (415) 973-6184.



Reference	Standard Dimensions (inches)	Nearest Metric Equivalent (millimeters)
A	2.0	50.7
K (GU5.3)	0.94	24 (2)
N	1.5	38.4
R_1	1.8	46.3
R_2	0.8	21.1
V	0.09	2.4
W	1.8	48.0

Notes
1 Below this line the corresponding gauge applies.
2 The free space requirements for the lamp neck and lampholder of ANSI C81.61 and C81.62 apply.

General Description: LED MR16 12V 10° NSP replacement lamp

Lamp Type: MR16

Replacement for: Halogen 20 Watt or higher

Voltage: 12V AC

Target Power factor ≥ 0.70

Minimum Luminous Efficacy: 45 lm/W

Base: GU 5.3 bi-pin base

Physical Fit: Equal to standard MR16 Halogen incumbent lamp, replacement lamp must fit into RSA Combolight Recessed Low-Voltage MR16 Trimless Standard Fixture

Beam angle at 50% of Maximum Intensity (deg): 10°

Target CBCP (cd): 3,000

Minimum Lumen Output ≥200 lumens

Minimum Life expectancy: 25,000 hours

Target Lumen Maintenance: ≥ 70% lumen maintenance (L70) at 25,000 hours of operation

Target CCT: 3000K ± 200K

Target Duv: 0.000±0.003

Chromaticity Maintenance: change of chromaticity within 0.007 on the CIE 1976(u'v') diagram over the minimum lumen maintenance test period of 6,000 hours

Color Rendering:

1. Color Rendering Index (CRI) ≥80 and R9≥50

OR

2. Color Quality Scale (CQS) ≥85

Flicker: No perceptible flicker

Warranty Terms: a warranty must be provided for lamps covering material repair or replacement for a minimum of three years (3) from date of purchase

Dimming: Lamps may be dimmable or non-dimmable. Lamps used in this demonstration will not be dimmed, but lamps will be operated on a multi-floor architectural dimming system

Documentation Requested: Copies of LM-79 Test reports done at a DOE CALiPER-Recognized or NVLAP-Accredited testing facility

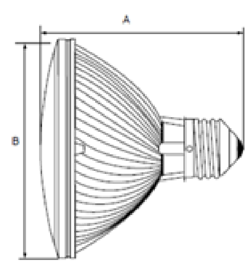
A.3 LED Replacement for Halogen PAR30 Short Neck 75-Watt 40° Flood Lamp Specification

A.3.1 Overview

The DOE GATEWAY program's three stated goals are to field test SSL technology that: matches or improves the quality of existing lighting, reduces overall energy consumption and is cost effective for the end user. This GATEWAY Demonstration project will study the applicability of using commercially available light-emitting diode (LED) lamps as replacements for halogen lamps. Participants in this demonstration project include a high-end hotel in San Francisco, LED lighting manufacturers, Lighting Designers, Interior Designers, PG&E and the Pacific Northwest National Laboratory (PNNL). LED lamps used in this project will be installed in three common areas of the hotel test site to replace the current high CRI Halogen lamps. These LED lamps will need to satisfy the quality requirements of the hotel guests, the hotel owners, management, employees, as well as the lighting designers, interior designers, electrical utility and researchers involved in this project. The LED lamps will be evaluated in terms of qualitative aspects as well as their energy efficiency and cost-effectiveness. Replacement lamps will not be dimmed, but must be compatible with the existing fixtures and dimming system. They must reduce energy consumption and lower the life-cycle costs of the hotel's existing lighting system. This project is supported under the U.S. Department of Energy (DOE) Solid-State Lighting Program. PNNL manages GATEWAY demonstrations for DOE and represents their perspective in the conduct of the work. PG&E and PNNL will conduct in situ measurements and analysis of the results. Quantitative and qualitative measurements of light and electrical power will be taken at the site for both Halogen and LED light sources. Lamps selected for this project will be installed at the site in March 2010 and periodically assessed until 2012.

A.3.2 Time Line

Request for lamp submissions and documentation will be released Friday, January 22, 2010. Manufacturers who would like to participate must submit three (3) lamps plus documentation for testing and review by Wednesday, January 27, 2010. Only lamps that are currently available in needed quantities and deliverable by March 15th, 2010 will be considered for this project. The candidate lamps submitted will be tested and visually evaluated, and final selections of lamps for this demonstration project will be based on best overall match to the needs of the project. Lamps should strive to meet the Energy Star Integral Lamp Specification (http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegralLampsFINAL.pdf). Lamp selections will be made by February 1, 2010 and the lamp manufacturer/supplier will be notified. Lamps will be installed in the hotel during the third week of March. If you would like to be considered as a partner in this demonstration, please send the lamp samples and performance documentation to: Thor E. Scordelis, Sr. Program Manager Pacific Gas & Electric Company, 245 Market Street, Room 395B San Francisco, CA 94105 (415) 973-6184.



	(A)	(B)
Bulb	MOL	Bulb Diameter
PAR30	3 5/8	3 3/4

General Description: LED PAR30 short neck 40° flood replacement lamp

Lamp Type: PAR30 Short Neck

Replacement for: Halogen 75 watt or higher

Voltage: 120V AC

Power factor ≥ 0.70

Minimum Luminous Efficacy: 45 lm/W

Base: E26 Medium, short neck

Physical Fit: Equal to Standard PAR- 30 short neck Halogen incumbent lamp. Replacement lamp must fit into Kurt Versen C7327 Recessed Downlight PAR- Lamp 5" Conoid aperture fixture. Maximum lamp overall length and diameter not to exceed target lamp dimensions.

Beam angle at 50% of Maximum Intensity (deg): 40°

Target CBCP (cd): 2,100

Minimum Lumen Output ≥500 lumens

Minimum Life expectancy: 25,000 hours

Lumen Maintenance: ≥ 70% lumen maintenance (L70) at 25,000 hours of operation

Target CCT: 3000K ± 200K

Duv: 0.000±0.003

Chromaticity Maintenance: change of chromaticity within 0.007 on the CIE 1976(u'v') diagram over the minimum lumen maintenance test period of 6,000 hours

Color Rendering:

1. Color Rendering Index (CRI)≥80 and R9≥50

   OR

2. Color Quality Scale (CQS) ≥85

Flicker: No perceptible flicker

Warranty Terms: a warranty must be provided for lamps covering material repair or replacement for a minimum of three years (3) from date of purchase

Dimming: Lamps may be dimmable or non-dimmable. Lamps used in this demonstration will not be dimmed, but lamps will be operated on a multi-floor architectural dimming system

Documentation Requested: Copies of LM-79 Test reports done at a DOE CALiPER-Recognized or NVLAP-Accredited testing facility

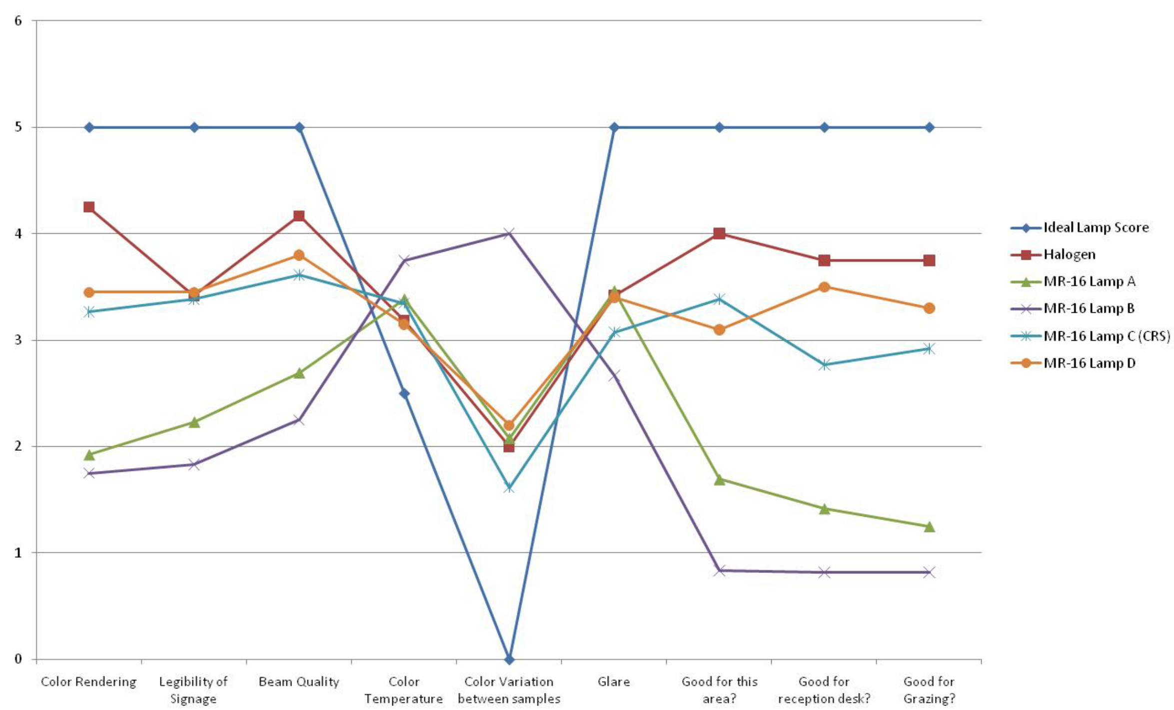
Appendix B

Round 2 - Evaluation Team Survey of Elevator Lobby MR16 Lamp Quality

Appendix B - Round 2 – Evaluation team Survey of Elevator Lobby MR16 Lamp Quality

1. Does this light make the wood finishes look appealing? (0=Unacceptable, 5=Excellent)
2. Is the signage easy to see and read? (0=Unacceptable, 5=Excellent)
3. The beam quality (e.g., even color, even light distribution, no distracting halo or spill, no ragged beam edge) of this light is? (0=Unacceptable, 5=Excellent)
4. The color temperature of the light is? (0=Too warm, 5=Too cool)
5. The visible variation in color temperature among the 6 lamp samples are? (0=Not noticeable, 5=Very noticeable)
6. Glare from the light is: (0=Disabling, 5=Non-existent)
7. The lighting system for this lobby is: (0=Unacceptable, 5=Excellent)
8. Will this lamp be acceptable at the Registration Desk? (0=Unacceptable, 5=Excellent)
9. Will this lamp be acceptable for the Registration desk wall grazing? (0=Unacceptable, 5=Excellent) More/ Other Comments for discussion: (flicker, color appearance of finishes, skintones, paper, etc).

Average Survey Responses - Elevator Lobby MR16 Lamp Quality



Appendix C

GATEWAY Survey Questions

Appendix C – GATEWAY Survey Questions

GATEWAY Survey Questions

Please circle the response that most closely matches your own opinion

1. The lighting _____ my ability to see the objects that are on top of and around the Registration desk
    1. Greatly enhances
    2. Enhances
    3. Has no effect on
    4. Reduces
    5. Greatly reduces

2. Under the Registration desk lighting it is ____ to read text and perform writing tasks
    1. Very easy
    2. Somewhat easy
    3. Neither easy nor difficult
    4. Somewhat difficult
    5. Very difficult

3. The Registration desk lighting _____ my ability to distinguish or identify faces or objects
    1. Greatly enhances
    2. Enhances
    3. Has no effect on
    4. Reduces
    5. Greatly reduces

4. The uniformity of light across the registration desk is _____
    1. Too spotty
    2. Acceptably spotty
    3. Neither too spotty or too even
    4. Acceptably even
    5. Too even

5. The Registration desk lighting is _____
    1. Glaring
    2. Somewhat glaring
    3. Neither glaring nor comfortable
    4. Somewhat comfortable
    5. Comfortable

6. The lighting level in the Registration area is _____
    1. Too dim
    2. Somewhat dim
    3. Just right
    4. Somewhat bright
    5. Too Bright

7. The colors of wood, fabrics, and skin tones at and around the Registration desk appear
    1. Natural
    2. Somewhat natural
    3. Neutral
    4. Somewhat unnatural
    5. Very unnatural

8. Under the Registration desk lighting it is _____ to distinguish color
    1. Very easy
    2. Somewhat easy
    3. Neither easy nor difficult
    4. Somewhat difficult
    5. Very difficult

9. The visible variation in color among the different light fixtures is _____
    1. Not at all noticeable
    2. Somewhat noticeable
    3. Neutral
    4. Somewhat noticeable
    5. Very noticeable (Unacceptable)

10. The warmness or coolness of the lighting in the reception area is _____
    1. Much too cool (i.e. blue)
    2. Somewhat cool
    3. Just right
    4. Somewhat warm
    5. Much too warm (i.e. yellow or red)

11. The overall impression of the Registration desk area under this lighting is ______
    1. Exceptional
    2. Favorable
    3. Adequate
    4. Unfavorable
    5. Unacceptable

12. I _____ recommend use of this type of lighting elsewhere
    1. Would definitely
    2. Would
    3. May or may not
    4. Would not
    5. Would definitely not

13. Do you have any comments or observations of the lighting in the Registration Desk area?

____
____
____
____
____
____
____
____

Optional, for classification purposes only:

14. Year of birth
  ○ 1990 - 1999
  ○ 1980 - 1989
  ○ 1970 – 1979
  ○ 1960 - 1969
  ○ 1950 - 1959
  ○ 1940 - 1949
  ○ 1930 - 1939
  ○ 1920 - 1929
  ○ Before 1920

15. Gender:
  ○ Male ○ Female

16. How long have you worked at the Intercontinental Hotel? ____ years

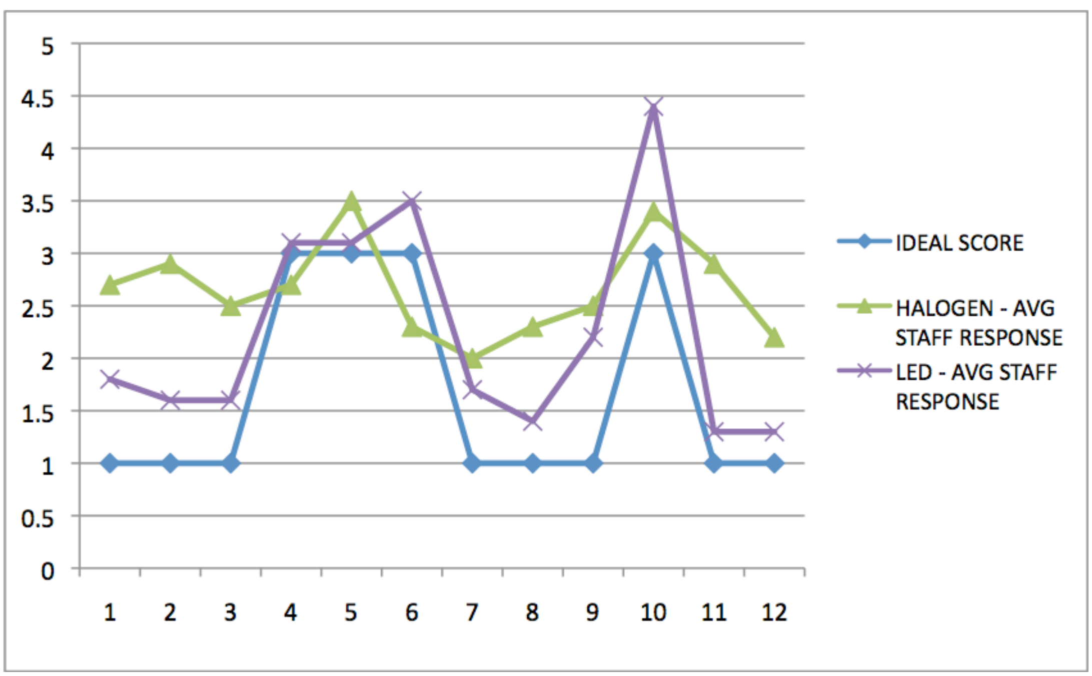


Figure C.1. Plot of Staff Responses to Before (Halogen) and After (LED) Lamping of the Registration Desk Area. Horizontal axis numbers correspond to survey question numbers, vertical axis to survey responses.

Appendix D

Appendix D

GATEWAY Project: InterContinental Hotel, San Francisco																
Incumbent Lamping																
Area	Fixture Type	Lamp Qty	Incumbent Manuf.	Lamp	Rated Life (hours)	Watts	Dimming setting day (perceived)	Dimming setting night (perceived)	Average day/night dimming setting and wattage multiplier	Total Annual Energy Use (kWh)	Lamp Cost	Multiplier of lamp life based on dimming level**	Average lamp life extended by dimming	Number of replacement lamps needed per year (8760 hours)	Annual lamp replacement cost	Annual $50 per lamp spot replacement labor cost
Reception Desk																
Front Desk Area (101A)	A5-1	7	Philips	MR-16 IR NFL 25	5000	30	0.7	0.5	0.6	1103.76	$ 8.20	3.00	15000	4.09	$ 33.52	$ 204.40
Front Desk Area (101A)	A8	217	Philips	MR-16 IR NSP 10	5000	20	0.85	0.5	0.675	25662.42	$ 8.00	3.00	15000	126.73	$ 1,013.82	$ 6,336.40
Front Desk Area (101A)	A6-1	6	Sylvania	PAR30 IR (short neck) FL 40	3000	75	1	0.35	0.875	3449.25	$ 14.00	3.00	9000	5.84	$ 81.76	$ 292.00
Lobby Guest Elevator	A74	6	Philips	MR16 IR NFL 25	5000	30	0.8	0.8	0.8	1261.44	$ 8.20	3.00	15000	3.50	$ 28.73	$ 175.20
4th Floor Meeting Rooms Emergency DownLights																
4th Floor Meeting Rooms Emergency DownLights	A26	12	Sylvania	PAR30 IR long neck FL 40	3000	75	1	1	1	7884	$ 14.00	1.00	3000	35.04	$ 490.56	$ 1,752.00
3rd Floor Meeting Rooms Emergency DownLights	A26	6	Sylvania	PAR30 short neck 25 degree	3000	75	1	1	1	3942	$ 14.00	1.00	3000	17.52	$ 245.28	$ 876.00
Guest Rooms Floor																
7th floor Elevator Lobbies, Art walls, Signage	A74	11	Philips	MR16 IR NFL 25	5000	30	1	1	1	2890.8	$ 8.20	1.00	5000	19.27	$ 158.03	$ 963.60
8th floor Elevator Lobbies, Art walls, Signage	A74	11	Philips	MR16 IR NFL 25	5000	30	1	1	1	2890.8	$ 8.20	1.00	5000	19.27	$ 158.03	$ 963.60
9th floor Elevator Lobbies, Art walls, Signage	A74	11	CRS	MR16 NFL 25	5000	30	1	1	1	2890.8	$ 8.20	1.00	5000	19.27	$ 158.03	$ 963.60
TOTALS										**51,975.27**					**$ 2,209.74**	**$ 11,563.20**

** When the dimming level is less than 90% of rated voltage, filament evaporation no longer determines halogen lamp life. Combinations of other field factors such as shock, vibration, and temperature dominate the mode of failure. For this reason, GATEWAY uses a maximum life multiplier of 3, which is more consistent with the hotel's anecdotal relamping history.

GATEWAY Project: Intercontinental Hotel, San Francisco											
LED Replacement Lamping											
Area	**Fixture**	**Lamp QTY**	**Manufacturer**	**Lamp**	**Rated Lamp Life**	**Watts**	**Total Annual Energy Use (kWh)**	**Lamp Cost**	**Initial Retrofit cost (Lamp cost + $3 per lamp labor, group relamping)**	**Annual Lamp replacement Cost (3 year warranty)**	**Annual spot relamping (assume 10% annual replacement, $50 per lamp labor cost)**
Reception Desk											
Front Desk Area (101A)	A5-1	7	CRS	MR-16 NFL 26degree	25000	6	367.92	$ 65.00	$ 476.00	$ -	$ 35.00
Front Desk Area (101A)	A8-1	217	CRS	MR-16 NFL 26degree	25000	6	11,405.52	$ 65.00	$ 14,756.00	$ -	$ 1,085.00
Front Desk Area (101A)	A6-1	6	PHILIPS	PAR30 (short neck) 25 degree	25000	11	578.16	$ 60.00	$ 378.00	$ -	$ 30.00
Lobby Guest Elevator	A74	6	CRS	MR-16 NFL 26degree	25000	6	315.36	$ 65.00	$ 408.00	$ -	$ 30.00
Meeting Rooms Emergency DownLights											
4th Floor Meeting Rooms Emergency DownLights	A26	12	PHILIPS	PAR30 short neck 25 degree	25000	11	1,156.32	$ 60.00	$ 756.00	$ -	$ 60.00
3rd Floor Meeting Rooms Emergency DownLights	A26	6	PHILIPS	PAR30 short neck 25 degree	25000	11	578.16	$ 60.00	$ 378.00	$ -	$ 30.00
Guest Rooms Floor											
7th floor Elevator Lobbies, Art walls, Signage	A74	11	CRS	MR16 NFL 25	25000	6	578.16	$ 65.00	$ 748.00	$ -	$ 55.00
8th floor Elevator Lobbies, Art walls, Signage	A74	11	CRS	MR16 NFL 25	25000	6	578.16	$ 65.00	$ 748.00	$ -	$ 55.00
9th floor Elevator Lobbies, Art walls, Signage	A74	11	CRS	MR16 NFL 25	25000	6	578.16	$ 65.00	$ 748.00	$ -	$ 55.00
TOTALS		**287**					**16,135.92**		**$ 19,396.00**	**$ -**	**$ 1,435.00**

Appendix E

NIST BLCC 5.3-09: Comparative Analysis

Appendix E – NIST BLCC 5.3-09: Comparative Analysis

NIST BLCC 5.3-09: Comparative Analysis

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

Base Case: Gateway Project Halogen

Alternative: Gateway Project LED

General Information

File Name:	C:\Documents and Settings\D3Y335\My Documents\Gateway Demonstration Projects\Intercontinental Hotel Group\Reports and minutes and BLCC\BLCC Calcs\IHG replacement lamp with initial labor BLCC Calcs.xml
Date of Study:	Tue Oct 12 18:48:31 PDT 2010
Project Name:	Inter-Continental Hotel San Francisco
Project Location:	California
Analysis Type:	FEMP Analysis, Energy Project
Analyst:	KCurry and Naomi Miller
Base Date:	April 1, 2009
Service Date:	April 1, 2009
Study Period:	3 years 0 months(April 1, 2009 through March 31, 2012)
Discount Rate:	7.3%
Discounting Convention:	End-of-Year

Comparison of Present-Value Costs

PV Life-Cycle Cost

	Base Case	**Alternative**	**Savings from Alternative**
Initial Investment Costs:			
Capital Requirements as of Base Date	$0	$19,396	-$19,396
Future Costs:			
Energy Consumption Costs	$16,593	$5,151	$11,442
Energy Demand Charges	$0	$0	$0
Energy Utility Rebates	$0	$0	$0
Water Costs	$0	$0	$0

Recurring and Non-Recurring OM&R Costs	$30,189	$3,746	$26,442
Capital Replacements	$2,210	$0	$2,210
Residual Value at End of Study Period	$0	$0	$0
	------------	------------	------------
Subtotal (for Future Cost Items)	$48,992	$8,898	$40,094
	------------	------------	------------
Total PV Life-Cycle Cost	$48,992	$28,294	$20,698

Net Savings from Alternative Compared with Base Case

PV of Non-Investment Savings	$37,884
- Increased Total Investment	$17,186

Net Savings	$20,698

Savings-to-Investment Ratio (SIR)

SIR = 2.20

Adjusted Internal Rate of Return

AIRR = 39.67%

Payback Period

Estimated Years to Payback (from beginning of Service Period)

Simple Payback occurs in year	2
Discounted Payback occurs in year	2

Energy Savings Summary

Energy Savings Summary (in stated units)

Energy	-----Average	Annual	Consumption-----	Life-Cycle
Type	**Base Case**	**Alternative**	**Savings**	**Savings**
Electricity	51,975.3 kWh	16,135.9 kWh	35,839.4 kWh	107,444.5 kWh

Energy Savings Summary (in MBtu)

Energy Type	-----Average Base Case	Annual Alternative	Consumption----- Savings	Life-Cycle Savings
Electricity	177.3 MBtu	55.1 MBtu	122.3 MBtu	366.6 MBtu

Emissions Reduction Summary

Energy Type	-----Average Base Case	Annual Alternative	Emissions----- Reduction	Life-Cycle Reduction
Electricity				
CO2	27,949.37 kg	8,676.99 kg	19,272.38 kg	57,777.58 kg
SO2	6.69 kg	2.08 kg	4.61 kg	13.83 kg
NOx	22.66 kg	7.03 kg	15.62 kg	46.83 kg
Total:				
CO2	27,949.37 kg	8,676.99 kg	19,272.38 kg	57,777.58 kg
SO2	6.69 kg	2.08 kg	4.61 kg	13.83 kg
NOx	22.66 kg	7.03 kg	15.62 kg	46.83 kg

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