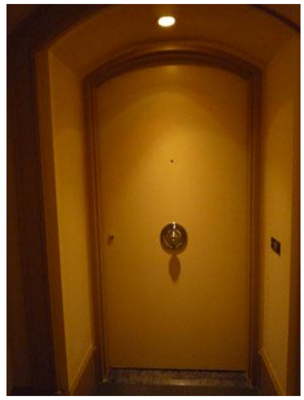

LED
Direct Replacement Lamp
Lighting Assessment

ET09SDGE0005

December 14, 2009

Prepared for:

SDGE
A Sempra Energy utility

Prepared by:

Emerging Technologies Associates, Inc.

Preface

PROJECT TEAM

This project is sponsored by San Diego Gas & Electric's (SDG&E®) Emerging Technologies Program (ETP) with Jerine Ahmed as the project manager. Quentin Yates of the Meridian was the contact and project manager. Daryl DeJean (daryldejean@gmail.com) of Emerging Technologies Associates, Inc. (ETA) provided the overall coordination of all parties involved, technical consulting and finalizing the report.

DISCLAIMER

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ACKNOWLEDGEMENTS

We would like to acknowledge Quentin Yates and the Homeowners Association Board of Meridian for assisting in reviewing the products and installation of the LED fixtures. Without their participation, this assessment project would not have been possible.

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Abbreviations and Acronyms

CCT Correlated Color Temperature

CFL Compact Fluorescent Lamp

CRI Color Rendering Index

DOE Department of Energy

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

FC Foot Candle

GWh Gigawatt hours

ICAT Insulation Contact and Air Tight

K Kelvin

kW Kilowatt

kWh Kilowatt hours

LED Light Emitting Diode

MW Megawatt

MWh Megawatt hours

PAR Parabolic Aluminized Reflector

SDG&E® San Diego Gas & Electric

SSL Solid State Lighting

TWh Terawatt hours

W Watts

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Executive Summary

San Diego Gas & Electric (SDG&E®) was interested in evaluating LED technology for general illumination in multi-family residential applications. The objective of the project was to determine the energy savings potential provided by direct replacement LED lamps as compared to the existing base case incandescent lamp.

Meridian Condominium Homeowners Association agreed to participate in an assessment to determine the viability of an LED solution in the interior common areas. SDG&E®'s Emerging Technologies Program considered the Meridian as an ideal host site due to the dramatic increase in condominium market in San Diego. According to a San Diego Housing News article dated August 3, 2009, 8000 condominium units have been added in downtown San Diego from 2001 to 2007. In an effort to address this significant growth, this project offered the opportunity to identify an energy efficient solution to meet the increasing electric demand head on. **Further, the results of this project apply to both the residential and commercial market segments.**

A key element of the scope of work was ensuring that the selected LED direct replacement lamp met the customer's expectation of proper light characteristics as well as Meridian's interior design and esthetics requirements.

Quantitative and qualitative light and electric power measurements were taken throughout the project. The achieved reductions in demand and energy are shown below in Table 1. Based upon the energy cost savings, the simple payback is shown below in Table 2.

Table 1: Energy and Demand Savings

Lamp	Power/Unit (W)	Number of Units	Demand (kW)	Energy (kWh)	Energy Savings (%)
Incandescent	30	172	5.2	45,202	-
LED	5.2	172	0.9	7,835	83

Table 2: Simple Payback - Energy Cost Savings

Lamp	Number of Units	Product Cost ($)	Installation Cost ($)	Total Investment ($)	Energy Cost Savings ($)	Simple Payback (years)
Incandescent	172	-	-	-	-	-
LED	172	8,600	1,120	9,720	5,231	1.9

This assessment project will assist residential as well as commercial building managers and owners across the country when considering LEDs as a new retrofit option for indoor general illumination lighting, i.e. common areas and corridors, meeting their energy efficiency as well as interior design and esthetic needs. The result from this assessment substantiates previous studies and illustrates the rapid pace of advancement in LED technology. PG&E previously conducted a similar assessment noting the potential of LED technology in the hospitality market segment. SDG&E® recently completed an assessment in the retail market segment with similar results.

Based upon the findings of this project, it is recommended that future projects conducted consider expanding the scope of work to include lighting and interior design review process to determine the key requirements to further the specification and acceptance of LED technology in general illumination applications. LED technology's ability to meet the light performance characteristics of interior applications without compromising the design and esthetic requirements is crucial at this juncture. Additionally, studies of the customer acceptance of emerging or new technologies such as LED's for interior general illumination applications would be important to the adoption of high energy efficiency lighting measures.

Introduction

In response to an overwhelming interest in innovations in LED lighting technology for the indoor lighting applications, San Diego Gas & Electric's Emerging Technologies Program objective with this assessment was to:

- identify potential LED solutions for interior downlights
- assess LED lighting technologies, validating manufacturer's claims regarding energy savings, light levels and light characteristics
- perform a comparison of the new lamp technology against traditional incandescent lamp to determine customer acceptance levels of the new LED technologies

The Meridian is a twenty-four year old luxury residential condominium building containing 172 units located in the Marina District of the City of San Diego. During 2008, Meridian management began looking into ways to save energy in its interior lighting. Unfamiliar with all of the available lighting technologies, Meridian contacted San Diego Gas & Electric's Emerging Technologies Program for assistance in their quest for energy-saving solutions.

In collaboration with Meridian, SDG&E® selected and arranged for the installation of new LED lighting to replace an existing incandescent downlight located at the entryway to each residential unit. Meridian and SDG&E® screened several LED PAR20 samples from various manufacturers. As a result of the screening process, LED direct replacement lamps from two manufacturers were selected for conducting this project's side by side comparison of both LEDs and the base case incandescent. After a period allowing for homeowner feedback, Meridian informed SDG&E® that the lamps Correlated Color Temperature (CCT) was too white and needed to be warmer to meet the interior design needs of the Homeowners Association.

In an effort to meet the requirements of the designer and Homeowners Association, SDG&E® and Meridian management requested a manufacturer to customize (meaning not off the shelf product) a PAR20 LED direct replacement lamp containing two white and two amber diodes. After careful evaluation of the custom designed LED lamp sample, the designer for the Meridian Homeowners Association and residents approved the purchase and installation of the LED lamp.

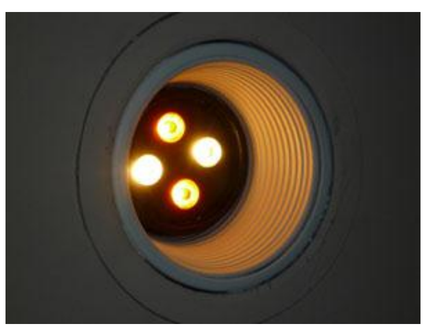


Figure 1: Selected 5 W LED with two white and two amber diodes

Project Background

PROJECT OVERVIEW

The LED Direct Replacement Lamp Lighting Assessment project was conducted as part of the Emerging Technologies Program of San Diego Gas & Electric Company. The Emerging Technologies Program "is an information-only program that seeks to accelerate the introduction of innovative energy efficient technologies, applications and analytical tools that are not widely adopted in California. The information includes verified energy savings and demand reductions, market potential and market barriers, incremental cost, and the technology's life expectancy." Project management and methodology was provided by Emerging Technologies Associates, Inc.

The LED Direct Replacement Lamp Lighting Assessment project evaluated the applicability of LEDs in a residential building application and demonstrated the potential of LEDs for general illumination. Once selected and installed, the applicability of the LED technology was determined by light output and power usage, economic factors and resident acceptance.

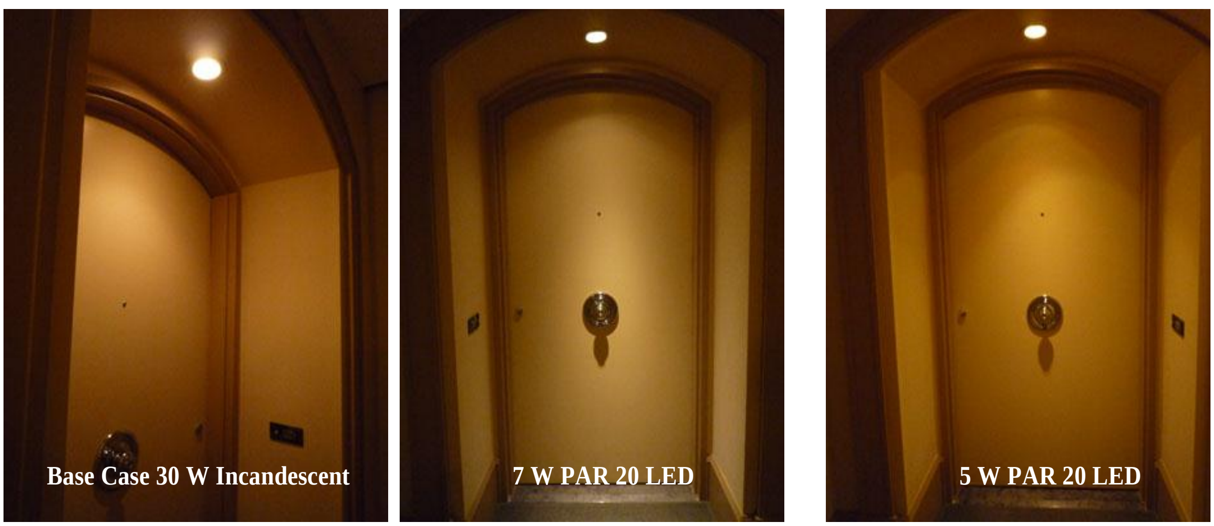


Figure 2: Side-by-side comparison of possible LED solution

The unique requirements of the customer to replace the existing 30 W incandescent PAR20 lamp with an LED providing identical CCT and CRI offering color quality and consistency with similar illuminance proved to be challenging. To assist in selecting the proper LED, 30 W PAR20 incandescent lamps were replaced with both 7 W and 5 W PAR20 LED lamps allowing the customer to select the desired LED manufacturer. The results of the comparison are shown in Table 3.

Table 3: Lamp Data

Characteristic	30 W PAR20 Incandescent*	7 W LED PAR20	5 W LED PAR20
CCT (K)	2,365	2,758	2,350
Illuminance (fc)	2.9	22.9	5.3
CRI (manufacturer data)	100	82	90
Stated life (hrs)	2,000	20,000	35,000

After a review by the Homeowner's Association and design team, the 5 W PAR20 LED was selected as it met the interior aesthetic requirements of the luxury condominium.

TECHNOLOGICAL OVERVIEW

The advancement of LED technology since the advent of white LED's presents some significant energy saving opportunities in general illumination. "Recessed downlights are the most commonly installed type of lighting fixture in residential new construction. New developments in LED technology and luminaire design may enable significant savings in this application," according to the US Department of Energy (DOE) Efficiency & Renewable Energy Program

(http://www1.eere.energy.gov/buildings/ssl/recessed.html).

The most common light source utilized to illuminate downlight applications is a 65-watt incandescent reflector-style lamp with a standard Edison base. Other common lamps are A-type incandescent lamps and spiral or reflector CFL's. The applications for recessed downlights include general ambient lighting needs in hallways, kitchens, bathrooms, bedrooms, offices, dens and other special areas.

Overall, the performance of LED technology is quickly gaining efficiency but the cost remains a barrier to market entry. However, it should be noted that the costs of white LED products seems to be getting more competitive in the market place with each year that passes and technological advances are reaching many more indoor lighting applications.

In addition to their significant energy savings advantage over incandescent lamps, LED recessed downlights have other technological benefits that should be taken into account in calculating the lifetime savings of the new technology:

- longer operating life
- lower maintenance and life cycle costs
- decrease in radiated heat level
- minimum light loss over the life of the lamp
- dimmability and controllability
- directional illumination and reduction of wasted light

MARKET OVERVIEW

The market potential for LED's to displace incandescent lamps is significant. The light output of a traditional recessed downlight is a function of the delivered lumens of the lamp and the efficiency of the fixture. Reflector-style lamps are typically directional in nature while "A" lamps and CFL's emit lights in all directions. This causes a significant quantity of light lost within the fixture. This quantity can be as much as 40% to 50%.

1. Size of the Market

According to Navigant, "the energy savings potential of LEDs for recessed downlights is significant, more than the energy savings potential of any other niche application. With virtually no market penetration in 2007, LED recessed downlight products made their entry into the market in 2008." Navigant estimates that all recessed downlights in the U.S. consumed 103.1 TWh in 2007. Recessed downlights represent 12% of all residential light fixtures and 15% of lighting energy use in the U.S. Navigant estimated that there were installed base of 829 million recessed downlight fixtures in the U.S. in 2007.

2. Market Potential

Currently, the market penetration of LEDs in the recessed downlight market sector is estimated at 0%. Market penetration is expected to increase, as luminaire quality and efficacy rises.

a. The U.S. Lighting Market:

A 2008 Navigant Consulting study sponsored by the U.S. Department of Energy ("Savings Estimates of Light Emitting Diodes in Niche Lighting Applications.") evaluated six indoor white-light niche market applications: recessed downlights, refrigerated display case lighting, retail display, task lighting, office undershelf lighting and kitchen undercabinet lighting." If LEDs become standard technology in these six indoor white-light niche market applications, 108 TWh per year of electricity savings could be possible, equal to 1.1% of total annual primary energy consumption and 13% of electrical energy consumption for lighting in the U.S. in 2007".

b. The California Recessed Downlight Market:

California represents approximately 8.4% of the total energy consumption in the US. (*source: http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA*). Applying this 8.4% to the U.S. installed base of 829 million units recessed downlight fixtures results in **California having an estimated installed base of 69.6 million such fixtures.**

c. The Recessed Downlights Market in SDG&E® territory:

Based upon the applicability of the results of this project and the availability of detailed market data for the commercial market segment, the market potential provided is applicable to the commercial market segment only.

Using kWh sales figures from a 2006 study conducted by Itron, Inc. *("California Energy Efficiency Potential Study")*, the total consumption in SDG&E®'s service territory for lighting is calculated to be on the order of 4,093 GWh in 2002. This study also provides values for kWh derived from lighting use within SDG&E®'s commercial sector only. An estimated **2,411.6 GWh** of electricity was used for interior lighting applications in the commercial sector**.**

Assuming SDG&E® service territory equates to 7% (see Appendix A) of California's total installed base, it is estimated that SDG&E® has an installed base of 4.9 million recessed downlights in its service territory. A 100% market penetration would equate to approximately 313.5 GWh (applying the 13% national average for recessed downlight electric energy consumption to SDG&E® 2,411.6 GWh for lighting) reduction in electricity use. Realistically, market penetration will most likely not ramp up until the high first cost barrier of LED lamps is overcome. Assuming 0.5% market penetration each year, electricity savings is estimated to be 1.6 GWh annually. This translates into 523 kW of reduced demand assuming an average of 3060 annual operating hours (255 work days at 12 hours per day) for the entire commercial market. Additional demand reduction may be realized in the residential market.

Project Objectives

The objectives of this project were to examine electrical, lighting, and economic performance of LED lighting technology in an interior hallway when compared with the traditional incandescent light source. The potential electrical demand and energy savings were measured in terms of instantaneous lamp wattage and annual kWh usage based on annual hours of operation. Lighting performance was measured in terms of illuminance and CCT, in Kelvin (K). Homeowners Association and resident acceptance was sought by Meridian management. Finally, economic performance was calculated using the simple-payback for substitution in new installation or replacement scenarios. A payback taking into account lamp lifespan, maintenance costs, in addition to electrical cost savings was also completed.

Figure 3: 5 W PAR20 LED solution

Methodology

HOST SITE INFORMATION

The Meridian is a twenty-four year old luxury residential condominium building containing 172 units located in the Marina District of the City of San Diego.

Their interior hallway lighting is composed of 30 W incandescent lamps installed over the doorway of each of the 172 residential units. The lights operate 8,760 hours annually. The purpose of the lights operating 24/7 is to illuminate the interior corridors and doorways of the building since there is no daylight. The customer pays an average of $0.14 per kWh.

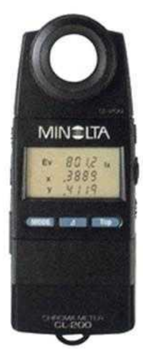
MEASUREMENT PLAN

A measurement plan was developed for the interior hallway lights to measure the lighting performance of each LED. Illuminance (in foot candles) and color temperature (in Kelvin) for the base case and LED lamp were taken. Instantaneous electrical power data for each light source was collected utilizing a WattsUp? PRO meter.

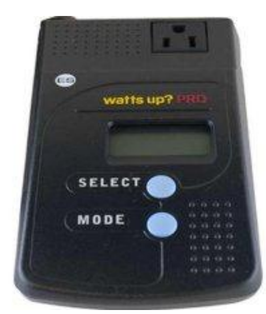
EQUIPMENT

The following equipment was used to collect the light and power characteristic data:

Illuminance and Correlated Color Temperature meter:
Konica Minolta Chroma Meter, Model CL-500



Power reading:
WattsUp? PRO
Accuracy: ±1.5%



Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The condominium has one hundred seventy-two 30 W PAR20 incandescent lamps which are located at each resident's entry door. The lamps operate 24 hours per day, or 8,760 hours annually. In addition to providing entry door lighting, these lamps also supplement lighting provided by wall sconces to illuminate the corridors. The base case PAR20 incandescent lamps drew 30 W. The selected LED direct replacement PAR20 lamp drew 5.2 W. A summary of the electric demand and energy savings are shown below in Table 4.

Table 4: Electric Energy and Demand Savings

Lamp	Power/Unit (W)	Number of Units	Demand (kW)	Energy (kWh)	Energy Savings (kWh)	Energy Savings (%)
Incandescent	30	172	5.2	45,202	-	-
LED	5.2	172	0.9	7,835	37,324	83

LIGHTING PERFORMANCE

Photopic illuminance and CCT readings were taken. Additionally, attention was given to the actual "look" of the light and the effect on the color scheme of the condominium. Before selecting the final replacement LED lamp, the Homeowner's Association Board and interior design team viewed the lamps to ensure the proper "look" was maintained. While this aspect is not measurable, it was perhaps the most critical of the performance criteria.

Table 5: Data for Selected 5 W PAR20 LED

Characteristic	30 W PAR20 Incandescent*	5 W LED PAR20
CCT (K)	2,365	2,350
Illuminance (fc)	2.9	5.3
CRI (manufacturer data)	100	85
Customer Acceptance	High	High

In an LD+A May 2007 article entitled "Are LEDs Ready for Recessed Downlights?", James Brodrick, Lighting Program Manager for the US DOE stated in 2006: "Several considerations are important when evaluating downlights in general. First, color quality and consistency are important. Often multiple downlights are installed in a space, and color variations are noticeable and undesirable. Second, glare can be a significant issue, particularly with downlights used for general ambient illumination. The fixture must be designed to balance the need for some light at relatively high viewing angles to avoid the "cave effect," while still minimizing discomfort glare. A third aspect, particular to residential settings, relates to downlights installed in insulated ceilings. Most states require them to be rated for insulation contact and air-tight (ICAT), which results in a high-temperature operating environment for the light source "

In this project, the words of James Brodrick were voiced by the customer. It was challenging to identify an LED solution offering the CCT, the color quality and consistency required by the customer. In an effort to ensure the consistency of each lamp, a MASTER sample was produced and specific variances were established for quality assurance.

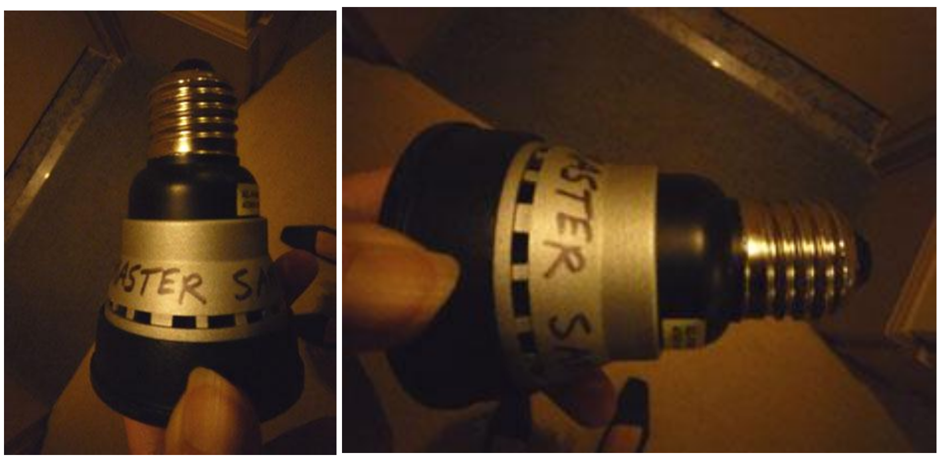


Figure 4: MASTER Sample 5 W LED

ECONOMIC PERFORMANCE

Important: The cost and equipment assumptions made in this section apply only to the Meridian. The Meridian was assessing the direct replacement of an incandescent light source to properly illuminate each resident's entry door and corridor. Readers should consider their specific variables such as maintenance, energy, luminaire/lamp costs and CCT requirements before drawing any conclusions about the cost effectiveness of LEDs. For LEDs, luminaire/lamp lifetime is a function of all components of the luminaire (LEDs, driver, housing, coatings, etc.), electrical and thermal properties. **Therefore, manufacturer claims, with regard to the aforementioned factors, are highly variable.** ***Although not currently included in category A of eligible Solid State Lighting products to qualify for ENERGY STAR, the ENERGY STAR criteria is used to determine acceptable life expectancy.*** The minimum life expectancy for a direct replacement LED to be eligible for ENERGY STAR qualification is 25,000 hours for the LED module/array for residential applications. The requirement is slightly higher, 35,000 hours, for commercial applications. (source: **ENERGY STAR Program Requirements for SSL Luminaires – Version 1.0** Sept. 12, 2007)

This section is based upon Meridian's cost and savings estimates, as provided by the General Manager, to evaluate economic performance of the base case incandescent and the LED light source assessed in this project. Both a simple payback as well as payback considering maintenance cost was calculated.

1. Energy Cost Estimates

The energy cost is based upon the customer's established rate of $0.14 (rounded to two decimals) per kWh. Meridian's resident entry door and corridor lighting operates 8,760 hours annually. ***The following table does not take into consideration the additional energy savings due to the reduced heat load resulting from the conversion to LED.***

Table 6 provides the energy cost and savings for the base case incandescent and the new LEDs installed at Meridian.

Table 6: Energy Cost Savings

Lamp	Number of Units	Power/Unit (W)	Energy (kWh)	Annual Energy Cost ($)	Energy Cost Savings ($)
Incandescent	172	30	45,202	6,328	-
LED	172	5.2	7,835	1,097	5,231

The simple payback calculations for a retrofit scenario considered the total investment cost and energy savings for the LED and are shown in Table 7. For the new construction scenario, the simple payback is shown in Table 8. Table 9 provides the analysis of the payback for a retrofit scenario when maintenance savings are included.

Table 7: Simple Payback – Retrofit

Lamp	Number of Units	Product Cost ($)	Installation Cost ($)	Total Investment ($)	Energy Cost Savings ($)	Simple Payback (years)
Incandescent	172	-	-	-	-	-
LED	172	8,600	1,120	9,720	5,231	1.9

Table 8: Simple Payback - New Construction

Lamp	Number of Units	Product Cost ($)	Installation Cost ($)	Energy Cost Savings ($)	Simple Payback (years)
Incandescent	172	602	-	-	-
LED	172	8,600	7,998	5,231	1.5

Note: Fixture, trim and installation cost assumed to be the same

Table 9: Retrofit Payback Based Upon Energy and Maintenance Savings

Lamp	Number of Units	Total Investment ($)	Annual Maintenance Cost ($)	Annual Maintenance Savings ($)	Energy Cost Savings ($)	Total Annual Savings ($)	Payback (years)
Incandescent	172	-	22	-	-	-	-
LED	172	9,720	4	18	5,231	5,249	1.8

2. Lamp Life

While LED technology appears to be a viable option for interior general illumination lighting, LED product quality can vary significantly among manufacturers. Therefore, it is recommended readers exercise due diligence when selecting LED technology for any application. It should be noted LED life and lighting performance are dependent upon proper thermal and electrical design; **without them, premature failure may occur.** Actual performance data documenting the life of LED luminaires does not yet exist due to the recent entry of LED technology into the general illumination market.

The theoretical life of high quality LED lamps is typically extrapolated from data collected when certain conditions are met. As contained in product technical data sheets for Philips LED products, "life expectancy is based upon engineering studies and statistical analysis." No exact metric is available to measure the performance of LED against other lighting technologies such as compact fluorescent or incandescent lamps. This does not mean that due to the rapid advancements in LED technology, one should rule LED out as a viable option. Readers must take into account the potential risk associated with LED technology without proper in situ testing. The DOE website contains reference materials on its Application Series: Comparing LED Recessed Downlights to Traditional Light Sources Fact Sheet containing Design and Specifications Considerations.

(http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/recessed_downlight.pdf)

The manufacturer of the LED direct replacement lamps assessed in this project claim life expectancies within those contained in the DOE ENERGY STAR Program requirements for Solid State Lighting Luminaires. In this project, the LED life is approximately 4 years which is at least twice the expected payback period in any of the above economic analyses. ***This is a conservative approach which indicates that in this application LEDs are a viable option to consider.***

3. Life Cycle Cost Analysis

To properly assess LED technology, a full life cycle cost analysis is recommended. There are many variables and considerations which are specific to each reader's situation. It is recommended that variables such as labor, cost of materials, maintenance practices, cost of financing, inflation, energy rates, material cost, premature failure rates, etc. be determined for the specific project under evaluation. The results described in this project pertain to this specific application and information of Meridian.

Due to the uncertainty as to future labor, product and other costs, especially for LED technology, readers are recommended to use their own judgment regarding the future costs. With the rapid advancements in LED technology, the pricing of the products may be reduced. ***Readers are encouraged to obtain current price quotes for LED direct replacement lamps as the LED market is in a state of flux. Furthermore, each project's economic analysis will yield its unique set of results depending upon the project sponsors and site requirements.***

Future Projects

This project illustrates the importance of educating the general public on the LED technology to gain customer acceptance of the emerging technology for indoor lighting applications. To increase the adoption of LED as a high energy efficiency lighting measures, the manufacturers, government agencies, stakeholders and industry associations promoting the technology must provide consumer education to increase the level of awareness of the special features of the technology such as binning.

LED technology's ability to meet the light performance characteristics of indoor area applications is here to stay. To fuel the adoption of high efficiency light sources such as LED's in the indoor lighting market will require:

- accurate technical information for LED lamps that address the light distribution and uniformity requirements of lighting required to properly light indoor spaces.
- further product development must be made to produce a range of CCT and color rendering properties to meet the unique needs of indoor spaces.
- educate and communicate not only this project's results on the variations in the mass production of diodes and the associated accepted range of CCT in bin sorting does not guaranty exact color consistency in lamps at this time.
- further studies of the market potential of LED lamps with warmer CCT is important at this juncture to satisfy the needs of the consumer market and the lighting designers and specifiers who require such. Additional attention must be paid to color rendering and how the LED light characteristics differ from other lighting technologies.

Conclusion

This assessment demonstrated that white-light LEDs have the potential to deliver comparable, if not better, lighting performance to incandescent light sources for general illumination in certain applications. For applications with significant annual operating hours such as the application in this project, LEDs provide high energy savings while offering significant operation and maintenance savings which offset the high first cost. The simple payback for this project was less than 2 years with an 83% reduction in energy.

This project attests to the incredible strides in technological innovations and enhancements of the LED manufacturing community with resulting quantifiable performance as well as design improvements that will fuel adoption in the long awaited largest sector of the lighting market, the interior general illumination lighting applications.

According to the Navigant Consulting 2008 report *("Savings Estimates of Light Emitting Diodes in Niche Lighting Applications")*, "LED penetration in indoor white-light applications has the potential to save substantial amounts of energy if the LEDs can achieve the stringent color quality and color-rendering requirements that the consumers demand in general lighting applications. As with colored–light applications, electricity is saved in white-light applications where LED sources are used to replace incandescent, halogen, and in some cases, CFL and certain types of fluorescents."

In an LD+A May 2007 article entitled "Are LEDs Ready for Recessed Downlights?", James Brodrick, Lighting Program Manager for the U.S. Department of Energy outlines a quick checklist for evaluating any LED downlights in applications. To corroborate the previous paragraph's statements, one of the key questions he recommends with a clarification of the need for in situ testing is: "Ask for information on the correlated color temperature and color rendering of the LEDs used, but don't depend exclusively on this data. Limitations of traditional color metrics with respect to LEDs, especially CRI, dictate the need to evaluate the luminaire in person."

A lesson learned during this project was that energy efficiency alone does not provide the driving force to adopt LEDs. In addition to energy efficiency, LEDs must provide the desired light characteristics, specifically CCT and CRI, to ensure the integrity of design and esthetics. Further, three key suggested actions learned in this project which may help fuel adoption of LED technology in interior spaces are:

1) Education of the consumer, commercial and industrial markets to help the LED manufacturers gain higher market adoption and reduce confusion over current performance standards whether they are qualification, labeling or testing standards by organizations such as IES or ENERGY STAR.
2) Market research on design and functionality from an interior designer's perspective is needed.
3) Industry and governmental stakeholders work to unify in finalizing standards across lighting technologies (induction, metal halides, LED, fluorescent and incandescent) by which the average consumer can make clear buying decisions.

Based upon the findings of this project and others, it is important to note that each situation is different. It is highly recommended that prior to committing to an LED application, readers conduct their own pilot or mini assessment of the available product options to meet the functional, design and energy efficiency needs of the end-users and determine the economic feasibility of their particular project.

Appendix A

SDG&E® Market Potential Calculations Reference

California Electricity Statistics & Data

http://www.ecdms.energy.ca.gov/elecbyplan.aspx

Electricity Consumption by Planning Area

Planning Area Description	Year	Total Usage
Burbank, Glendale, and Pasadena	2007	4155.237028
Dept. of Water Resources	2007	9956.406553
Imperial Irrigation District	2007	3563.224165
Los Angeles Department of Water	2007	25258.28371
Other	2007	1709.525015
Pacific Gas and Electric	2007	107987.2289
Sacramento Municipal Utility District	2007	10917.07883
San Diego Gas & Electric	2007	20492.55364
Southern California Edison	2007	100470.2711
	TOTAL	**284509.8089**
	SDG&E %	**7.202758216**

Appendix B

PG&E and SDG&E® Projects

Interior LED Lighting

PG&E Emerging Technologies Program

ETCC Report 0718

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

Key results:

Conclusions

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

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

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

In general, it is expected that the cost-effectiveness barrier will be overcome with maturing market conditions. Various incentive programs could also accelerate cost-effectiveness. PG&E uses this and other Emerging Technologies assessments to support the development of potential incentives for emerging energy efficient solutions. Because the performance and quality of the LED fixtures are critical to the long-term delivery of energy savings, it is important that incentive programs include quality control mechanisms. Incentive programs should include performance standards for qualifying products that include minimum criteria for warranty, efficacy, light distribution, and other important criteria.

Recommendations for Future Work

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

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

Field Performance

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

1) Lumen depreciation in solid-state lighting.

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

2) Conventional and LED lighting system design.

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

For more information, please visit:
http://www.etcc-ca.com/images/stories/ledhospitalitystudy_finalreport1.pdf

Retail LED Lighting Assessment

San Diego Gas & Electric

(report to be published)

In response to an overwhelming interest in innovations in LED lighting technology for the retail merchant market segment, San Diego Gas & Electric's objectives with this assessment were to:

- identify potential LED solution for the retail merchant market segment
- assess various manufacturers' products in LED lighting technologies, validating manufacturer's claims regarding energy savings, light levels and light characteristics
- perform a comparison of the new technologies against traditional high power incandescent technology in various applications, i.e. display case, focal point lighting, accent lighting etc.
- determine customer acceptance levels of the new LED technologies

Key results:

Conclusion

This assessment project demonstrated that a complete retail showroom "makeover" was accomplished. Significant energy savings (67% overall), improvement in customer comfort, enhanced lighting and consistency of product appearance, were possible while maintaining proper light intensity, CCT and CRI throughout the showroom area.

The lessons learned from this assessment are as follows:

- A complete replacement of focal point and display case lighting is possible and acceptable in a retail environment.
- The light qualities required by the retail market segment, regardless of the technology, must take into account the visual merchandising needs of the individual stores and address the following key metrics:
  - *Light Intensity*
  - *Color Rendering or " Honest Light" as described by the store owner*
  - *Attractive and Unobtrusive Light Fixtures*
  - *CCT*
  - *Interplay between different lighting systems is crucially important to achieve energy savings and meet the need to create the right "atmosphere" and elicit "good feelings" from the consumer*
- Adequate in situ testing must be completed before adopting new technologies.
- Cautious reliance on marketing brochures and technical data sheets
- Just because LED lighting does not achieve the same measured output as traditional lighting, does not mean it is not appropriate. LED lamps have tremendous potential in the right application within the store if it meets the visual merchandising needs.