Restaurant Ambient Lighting Demonstration Showcase

ET10SDGE0004

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Prepared for:

SDGE
A Sempra Energy utility

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Preface

PROJECT TEAM

This project is sponsored by San Diego Gas & Electric's (SDG&E®) Emerging Technologies Program (ETP) with Abdullah Ahmed (AAhmed1@semprautilities.com) as the project manager. Mike Hardin, Owner, was the contact and project manager for Hodad's San Diego (Hodad's). Daryl DeJean (daryldejean@gmail.com) of Emerging Technologies Associates, Inc. (ETA) provided technical consulting, data analysis, coordination of all parties involved, and finalized the report.

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ACKNOWLEDGEMENTS

SDG&E® and ETA would like to acknowledge Hodad's for their cooperation in the project. Without their participation, this demonstration project would not have been possible.

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Abbreviations and Acronyms

CALiPER Commercially Available LED Product Evaluation and Reporting

CFL Compact Fluorescent Lamp

DOE Department of Energy

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

kW Kilowatt

kWh Kilowatt hours

LCC Life Cycle Cost

LED Light Emitting Diode

MW Megawatt

MWh Megawatt hours

SDG&E® San Diego Gas & Electric

SSL Solid State Lighting

W Watts

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Executive Summary

San Diego Gas & Electric (SDG&E®) was interested in demonstrating LED technology in general illumination applications, especially restaurants. Hodad's agreed to participate in a demonstration to determine the viability of LED lighting solutions for their new restaurant. The goals of the project were to demonstrate the potential of LEDs in the restaurant sector and determine the energy savings potential provided by LED general illumination as compared to incandescent and fluorescent base cases.

Key elements of the scope of work were ensuring the selected LED luminaire used in the dining room met the requirements of maintaining the ambiance provided by incandescent and fluorescent lamps. With 42 incandescent lamps, 13 recessed downlights, and 52 fluorescent lamps proposed to be installed in the new restaurant, this demonstration project allowed for an ideal substitution of the designed base case incandescent and fluorescent with the LED solution.

The electric energy and demand savings achieved per LED lamp as compared to the technical data of the bases case are shown in Table 1. Based upon the annual operating cost savings and the installation cost of each type of lamp, the simple payback period for a retrofit is shown below in Table 2.

Table 1: Energy and Demand Savings

Lamp	Power/lamp (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Incandescent *	95	5,792	42	23,110	3.99	-
LED Direct Replacement	9	5,792	42	2,189	0.38	91
CFL *	23	5,792	13	1732	0.30	-
LED Retrofit Kit	11	5,792	13	828	0.14	52
Fluorescent *	32	5,792	52	9,638	1.66	-
Linear LED	22	5,792	52	6,626	1.14	31

** Base Case*

Table 2: Simple Payback – Retrofit

Lamp	Cost/lamp ($)	Number of Lamps	Total Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	2	42	84	23,110	0.20	4,622	-	-
LED Direct Replacement	25	42	1,050	2,189	0.20	438	4,184	0.23
CFL *	7	13	91	1,732	0.20	346	-	-
LED Retrofit Kit	50	13	650	828	0.20	166	180	3.11
Fluorescent *	7	52	364	9,638	0.20	1,928	-	-
Linear LED	60	52	3,120	6,626	0.20	1,325	603	4.57

** Base Case*

This demonstration project will assist numerous restaurant managers and owners across the country when considering LED technology as an option for restaurant general illumination applications meeting their energy efficiency goals while maintaining the desired ambiance that includes dimming. Individual restaurant requirements as well as economic considerations may directly impact the outcome of similar demonstration projects. Therefore, readers are advised that each installation is unique. It is recommended the reader exercise due diligence in selecting the appropriate LED technology specific to their needs.

Based upon the findings of this project, it is recommended that future projects consider the following:

- evaluate the benefits and acceptability of bi-level or adaptive lighting, including dimming
- the impact of an occupancy sensor based bi-level luminaire on demand and energy savings
- the impact of daylighting on energy efficiency for such general illumination applications

Introduction

In response to an overwhelming interest in innovations in LED lighting technology for indoor lighting applications, San Diego Gas & Electric's ETP conducted this demonstration project with the following objectives:

- identify potential LED solutions for indoor lighting which are capable of dimming, specifically general illumination applications
- substitution of the designed base cases with LED lighting technologies, validating manufacturer's claims regarding energy savings
- perform a comparison of LED technologies against traditional incandescent and fluorescent technologies in general illumination applications to determine customer acceptance levels of LED technologies

Hodad's, a famous burger restaurant, began considering options for their indoor general illumination needs when constructing their new location in San Diego, California. Due to the excitement surrounding solid-state lighting (SSL), Hodad's desired to be one of the first restaurants in San Diego to be completely illuminated by LEDs.

In collaboration with Hodad's, SDG&E® selected and arranged for the installation of LED lighting in the restaurant as a substitute for the designed incandescent and fluorescent lamps.

A visual inspection of the LED lighting was conducted by Hodad's owner and the SDG&E® Project Team. The purpose was to determine if the LED solutions met the restaurant's expected light levels and ambiance. The LED illumination was aesthetically pleasing and the owner expressed an overwhelming endorsement and acceptance of LED technology as a desirable lighting solution.

Project Background

PROJECT OVERVIEW

The Restaurant Ambient Lighting Demonstration Showcase project was conducted as part of the Emerging Technologies Program of San Diego Gas & Electric Company. The SDG&E® ETP "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." Emerging Technologies Associates, Inc. was retained by SDG&E® to manage the Restaurant Ambient Lighting Demonstration Showcase project, coordinate the participants and stakeholders, and conduct the data collection and analysis for the project.

The Restaurant Ambient Lighting Demonstration Showcase project showcased the applicability of light emitting diodes (LEDs) in a general illumination application, specifically a restaurant. At Hodad's restaurant, the designed base case incandescent lamps in the dining room were substituted with direct replacement LEDs, the hallway CFL lamps with recessed LED downlight retrofit assembly, and the kitchen fluorescent troffers with LED linear lamps. The applicability of the technology was determined by the customer's acceptance of the light levels and power usage and economic factors.

TECHNOLOGICAL OVERVIEW

At the time of this demonstration, LED lighting in indoor general illumination applications such as restaurants was not recognized as achievable, especially when dimming was required. However, SDG&E's ETP recognized the advancement of LED technology. Since the advent of high brightness LED's, SDG&E's ETP felt that LED technology may present some significant opportunities and it would be in the best interest of their programs to provide a full scale demonstration of LED lighting technologies in restaurant general illumination applications.

The most common light source utilized to illuminate restaurant indoor areas is incandescent. The reason for utilizing incandescent lamps is the belief that only an incandescent lamp can provide the proper illumination, the desired "warm" ambiance, and is compatible with dimming systems.

With the advent of LED light sources and published claims that LEDs can be dimmed and have a longer lamp life than both incandescent and CFL lamps, there is an interest in determining the validity of LEDs as a solution in numerous indoor lighting applications.

The performance of incandescent and CFL light sources is well documented with regard to lamp life and light characteristics. However, it is believed that a well-designed LED indoor lamp or luminaire can provide at least comparable light characteristics as incandescent and CFL light sources in a more efficient manner for general illumination applications.

The US Department of Energy (DOE) reports that LED technology is changing at a rapid pace. Overall, the performance of LED technology is quickly gaining efficiency but high initial cost remains a barrier to market entry. However, it should also be noted that the cost of LED technology seems to be getting more competitive in the market place with each passing year and technological advances are reaching requirements for indoor general illumination applications. A proper economic analysis of LED solutions confirming favorable payback, such as this project, may also help overcome the perceived high first cost.

MARKET OVERVIEW

Since downlights were part of this demonstration project and a snapshot of the market potential for downlights exists, the following overview was provided: The recessed downlight market provides tremendous opportunity for energy and demand savings. According to the Navigant Consulting, Inc. report entitled "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications," the commercial market segment has a total of 394, 086,000 recessed downlights with 313,548,000 of those still being incandescent consuming on average 72 watts each.[1]

Sector	Incandescent Recessed Downlights	CFL Recessed Downlights	Total
Residential	370,765,000	64,103,000	434,868,000
Commercial	313,548,000	80,538,000	394,086,000
Total	**684,313,000**	**144,641,000**	**828,954,000**

Figure 1: US Recessed Downlight Market

Reflector Lamp Type	Residential Average Wattage (W)	Equivalent Residential LED (W)	Commercial Average Wattage (W)	Equivalent Commercial LED (W)
Incandescent	72	14	72	14
CFL	11	7	16	11

Figure 2: Recessed Downlight Average Power

Year	Residential Average Operating Hours (hrs)	Commercial Average Operating Hours (hrs)
2007	843	3347

Figure 3: Recessed Downlight Average Annual Operating Hours

[1] Energy Savings Estimates of Light Emitting Diodes, Navigant Consulting Inc. , 2008

California represents approximately 8.4% of the total energy consumption in the US. [2] Applying this 8.4% to the installed base of recessed downlight fixtures of 394 million units results in California having an estimated installed base of 33.1 million of such fixtures. Assuming SDG&E® service territory equates to approximately 7% of California's total installed base[3], it is estimated that SDG&E® has an installed base of 2.3 million recessed downlight fixtures in its service territory. 100% market adoption for all recessed downlights would result in a reduction of 461,886 MWh and a demand of 138 MW. Assuming that the general illumination application comprises only 5% of the recessed downlight market, 100% market adoption for this application would only result in replacing 115,000 fixtures or lamps. Assuming 0.5% market penetration each year would result in an electricity savings of approximately 115.5 MWh annually using the average operating hours shown above in Figure 3. In SDG&E® service territory, this translates into 34.5 kW of reduced demand.

Realistically, market penetration will most likely not ramp up until the high first cost barrier of LED luminaires is overcome. Sharing the economic analysis of demonstration projects like this one may help fuel adoption.

[2] http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA
[3] Based upon statistics located at http://www.ecdms.energy.ca.gov/elecbyplan.aspx data found in Appendix A

Project Objectives

The objectives of this project were to quantify the energy efficiency and cost effectiveness of LED lighting technology in a restaurant general illumination application as compared to the traditional light sources of incandescent and fluorescent. In addition to the quantification of the benefits of LED lighting technology, the demonstration was to serve as an examination of the potential for LEDs in the restaurant sector. The potential electrical demand and energy savings were calculated in terms of stated system wattage of the base case versus the actual measured wattage of the LEDs. The restaurant lighting operates 5,792 hours (16 hours/day 362 days/year) annually.

The economic performance was calculated using the simple-payback for substitution in new installation or retrofit scenarios without consideration for additional energy savings due to dimming.

Methodology

HOST SITE INFORMATION

Hodad's is a famous burger restaurant with a new location in San Diego, California. The light sources which were specified for the indoor lighting of the restaurant were incandescent, CFL, and linear fluorescent. The dining room lighting was to be provided by forty-two 95 W incandescent lamps. The hallway was to be lit with thirteen 23W recessed downlights. The kitchen was to be lit with 13 troffers which utilized four 32W fluorescent lamps in each luminaire. Even though daylight is available from the windows, the dining room lights remain on for 16 hours each day since the dining room is a common area for customers to sit down and eat. The space should never appear to be dim. The fixtures were to be mounted at a height of 8 feet with spacing of 6ft between the incandescent fixtures, 4ft between the recessed downlight fixtures, and 4ft between the fluorescent fixtures. The lights operate 5,792 hours annually. The customer's blended electric cost is $0.20 per kWh.

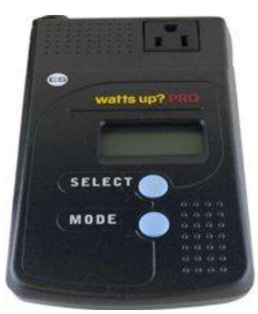
MEASUREMENT PLAN

Pre and post installation field visits were conducted. Instantaneous energy consumption for the LED lamps and luminaires were collected utilizing a WattsUp Pro meter (described below). To ensure visual acceptance the customer was asked for his opinion. The owner had several different restaurant personnel review the "new" lighting in order to ensure the design and ambiance of the restaurant were maintained.

EQUIPMENT

The following equipment was used to collect the power characteristic data. The meter was calibrated as per manufacturer specifications.

Power reading:
WattsUp Pro
Accuracy: ±1.5%



https://www.wattsupmeters.com/secure/products.php?pn=0&wai=316&spec=4

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The designed restaurant lighting consisted of 42 incandescent lamps, 13 recessed downlight fixtures, and 13 fluorescent 4 lamp troffers. Even though daylight is available, the lights remain on 16 hours per day. Incandescent, CFL, and fluorescent luminaires were expected to consume 95 W, 23 W, and 32 W respectively. The LED lamp replacement consumed 9 W, an energy savings of 91%. The LED recessed downlight kit consumed 11 W, resulting in a 52% energy savings. The LED linear lamp consumed 22 W, which translated to 31% energy savings. The results are summarized in Table 3.

Table 3: Energy and Demand Savings

Lamp	Power/lamp (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Incandescent *	95	5,792	42	23,110	3.99	-
LED Direct Replacement	9	5,792	42	2,189	0.38	91
CFL *	23	5,792	13	1,732	0.30	-
LED Retrofit Kit	11	5,792	13	828	0.14	52
Fluorescent *	32	5,792	52	9,638	1.66	-
Linear LED	22	5,792	52	6,626	1.14	31

** Base Case*

ECONOMIC PERFORMANCE

It is important to note that the cost and fixture assumptions made in this section apply only to the demonstration carried out at Hodad's restaurant in San Diego. Hodad's demonstrated a retrofit of incandescent, fluorescent, and CFL light sources. Readers should consider variables specific to their site such as maintenance, energy, luminaire/lamp costs and requirements for dimming before drawing any conclusions about the cost effectiveness of LED lamps or luminaires. For LED lamps and luminaires, 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.

1. Energy Cost Estimates

The calculated energy cost is based upon the Hodad's blended rate of $0.20 per kWh. Hodad's restaurant lighting operates 5,792 hours annually. Table 4 provides the energy cost and savings estimate assuming all the designed lighting was converted from the base case incandescent, CFL, and fluorescent to LED lamps/luminaires.

Table 4: Energy Cost Savings Achieved

Lamp	Number of Lamps	Annual Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Cost Savings (%)
Incandescent *	42	23,110	0.20	4,622	-	-
LED Direct Replacement	42	2,189	0.20	438	4,184	91
CFL *	13	1,732	0.20	346	-	-
LED Retrofit Kit	13	828	0.20	166	180	52
Fluorescent *	52	9,638	0.20	1,928	-	-
Linear LED	52	6,626	0.20	1,325	603	31

** Base Case*

The simple payback calculations for both scenarios considered the total product cost investment and energy savings for the LED retrofits. The results are summarized in Tables 5 and 6, respectively.

Table 5: Simple Payback – Retrofit

Lamp	Cost/lamp ($)	Number of Lamps	Total Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	2	42	84	23,110	0.20	4,622	-	-
LED Direct Replacement	25	42	1,050	2,189	0.20	438	4,184	0.23
CFL *	7	13	91	1,732	0.20	346	-	-
LED Retrofit Kit	50	13	650	828	0.20	166	180	3.11
Fluorescent *	7	52	364	9,638	0.20	1,928	-	-
Linear LED	60	52	3,120	6,626	0.20	1,325	603	4.57

** Base Case*

Table 6: Simple Payback – New Construction

Lamp	Cost ($)	Total Incremental Cost ($)	Number of Lamps	Total Incremental Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	52	-	42	-	23,110	0.20	4,620	-	-
LED Direct Replacement	75	23	42	966	2,189	0.20	438	4,184	0.23
CFL *	30	-	13	-	1,732	0.20	346	-	-
LED Retrofit Kit	50	20	13	260	828	0.20	166	180	1.44
Fluorescent *	40	-	52	-	9,638	0.20	1,928	-	-
Linear LED	85	45	52	2,340	6,626	0.20	1,325	603	3.88

** Base Case*

2. Luminaires and Lamp Life

This report uses the following lamp life in hours: LED direct replacement lamp – 50,000, recessed downlight LED retrofit kit – 50,000, and LED linear lamp – 50,000. The report uses 50,000 hours as the LED life expectancy, per the manufacturer and the DOE website.[4] James Brodrick, Lighting Program Manager, U.S. Department of Energy, Building Technologies Program, in a recent article entitled "Lifetime Concerns", when discussing how best to define the longevity of LED luminaires stated: "That's not a simple matter, because it doesn't just involve the LED themselves, but rather encompasses the entire system-including the power supply or driver, the electrical components, various optical components and the fixture housing."

Regarding LEDs, actual performance data documenting the life of LED luminaires/lamps does not yet exist due to the relative infancy of LED technology for indoor general illumination. While LED technology appears to be a viable option for indoor common area general illumination lighting, LED product quality can vary significantly among manufacturers. Therefore, it is recommended that readers exercise due diligence when selecting LED technology for any application. Readers should also be aware that LED life and lighting performance are dependent upon proper thermal and electrical design. Without the latter, premature failure may occur. Readers must properly assess the potential risk associated with LED technology that has not undergone proper testing.

3. Life Cycle Cost Analysis

Even though life cycle cost (LCC) analysis was not part of the scope of this project, a full life cycle cost analysis is recommended. There are many variables and considerations that 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, product life, etc. be determined for the specific project under evaluation.

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

[4] http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds.pdf

Conclusion

This demonstration project illustrated that properly designed LED luminaires can provide energy savings from 31% to 91% depending upon the lamp being replaced without significantly compromising the lighting performance required for restaurant general illumination applications. Of great interest was that a one-to-one replacement of fluorescent with LED linear lamps may not be necessary. After the installation and operating for several weeks, Hodad's reported that the light levels under the troffers seemed excessive. Subsequently, the project manager removed two lamps from each troffer that improved the energy efficiency and significantly reduced the payback period. By using only two linear LED lamp replacements, the energy savings from the retrofit increased from 31% to 66%, or from $603 to $1,265 annually. This in turn results in the payback for a retrofit and new construction of 1 year and 0.9 years, respectively.

A lesson learned during this demonstration project is that there are many factors that may be unique to each site, and require careful consideration. Each reader should consider their capital budgeting needs, maintenance and installation constraints, as well as any internal lighting standards. While the results of this demonstration indicate significant energy savings potential when LED lighting is used instead of incandescent, CFL, or fluorescent lighting, readers are encouraged to complete a life cycle cost analysis to gain the complete economic picture of a technological change out.

For general illumination applications within the restaurant, the LED solutions proved to be viable options. In addition, these LED solutions are applicable to many other indoor lighting applications. However, due to the unproven life of LEDs, economic claims based on reliability are based on the best available information from the manufacturer and DOE reports. Although favorable payback periods were achieved in this project, the payback periods are sensitive to annual operating hours, product costs, and the installation specific maintenance, and electrical costs.

It is important to note that each situation is different. Prior to committing to a technology, readers should conduct their own pilot or mini demonstration of the available options to determine the economic feasibility of their particular project.

For general information and programs on LED technology, it is recommended visiting the DOE SSL website: www1.eere.energy.gov/buildings/ssl. A recommended resource to assist in selecting LED solutions that have been mystery shopped to validate manufacturer claims is the DOE SSL Commercial Available LED Product Evaluation and Reporting (CALiPER) website: www1.eere.energy.gov/buildings/ssl/caliper.html. Other resources include the ENRGY STAR website: www.energystar.gov and the Lighting Facts website: www.lightingfacts.com.

Appendix

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	2009	2,293
Dept. of Water Resources	2009	5,748
Imperial Irrigation District	2009	3,319
Los Angeles Department of Water	2009	25,087
Other	2009	1,744
Pacific Gas and Electric	2009	108,504
Sacramento Municipal Utility District	2009	10,616
San Diego Gas & Electric	2009	**20,928**
Southern California Edison	2009	100,579
TOTAL		278,819

*Total Usage express in Millions of kWh

SDG&E **7.5 %**