Parking Structure LED Lighting Assessment

ET09SDGE0009

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Prepared for:

SDGE
A Sempra Energy utility®

Prepared by:

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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. Gary Rose, Facility Engineer, was the contact and project manager for Sharp Chula Vista Medical Center (Sharp). 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.

DISCLAIMER

This report was prepared as an account of work sponsored by SDG&E® ETP. 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 (all actual measurements unless stated otherwise), market potential and market barriers, incremental cost, and the technology's life expectancy."

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ACKNOWLEDGEMENTS

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

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Abbreviations and Acronyms

CCT Correlated Color Temperature

CLTC California Lighting Technology Center

DOE Department of Energy

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

FC Foot Candle

GWh Gigawatt hours

HID High Intensity Discharge

HPS High Pressure Sodium

K Kelvin

kW Kilowatt

kWh Kilowatt hours

LED Light Emitting Diode

MH Metal Halide

MWh Megawatt hours

PG&E® Pacific Gas & Electric

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 evaluating LED technology in parking structure applications. Sharp Chula Vista Medical Center (Sharp) agreed to participate in an assessment to determine the viability of an LED lighting solution for their parking structure. The goal of the project was to determine the energy savings potential provided by LED lighting as compared to the existing metal halide (MH) high intensity discharge (HID) base cases.

A key element of the scope of work was ensuring the selected LED luminaire met the customer expectations of improving the quality of the lighting, specifically uniformity.

Sharp was selected as an ideal site for the project due to the size of the parking structure. With only fourteen luminaires in the parking structure, seven on each side separated by parking stalls, the site allowed for an ideal side by side comparison of the base case MH and LED luminaires.

Quantitative and qualitative light and electric power measurements were taken throughout the project. Electric energy and demand savings per LED luminaire are shown in Table 1. Based upon the annual operating cost savings and installed cost of an LED luminaire, the simple payback period is shown below in Table 2.

Table 1: Demand and Energy Savings per LED Luminaire

Application	Lamp Watt	Fixture Watts	Annual Operating Hours	Total Demand (kW)	Annual Energy (kWh)	Reduction (%)
Metal Halide	250	291	8,760	0.29	2,549	
LED	139	141	8,760	0.14	1,235	52

Table 2: Simple Payback per LED Luminaire

Application	Total Installed Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Parking Structure	1,216	184	6.6

This assessment project will assist numerous facility managers and building owners across the country when considering LED luminaires as a retrofit option for lighting in parking structures towards meeting their energy efficiency as well as safety and security needs. Local site requirements, luminaire quality, as well as economic considerations may directly impact the outcome of similar assessment projects. **Therefore, readers are advised that each installation is unique. It is recommended the reader exercise due diligence in selecting luminaires specific to their needs.** The results of this project corroborate similar studies, specifically those conducted by Pacific Gas & Electric (PG&E®) and the California Lighting Technology Center (CLTC).

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

- evaluate the benefits and acceptability of bi-level or adaptive lighting
- a methodology to determine the impact of LED lighting on security cameras and the ability to clearly depict images in the parking structure.
- a survey of drivers parking their vehicles may provide valuable insight as to the perception and receptiveness of LED technology in a parking structure.
- the impact of an occupancy sensor based bi-level luminaire on demand and energy savings

Introduction

In response to an overwhelming interest in innovations in LED lighting technology for the outdoor area lighting applications, San Diego Gas & Electric's Emerging Technologies Program conducted this assessment with the following objectives:

- identify potential LED solution for outdoor area lighting, specifically parking structures, parking lot and entrance roadways
- assess 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 intensity discharge (HID) technology in the stated applications to determine customer acceptance levels of the new LED technologies

During 2008, Sharp Chula Vista Medical Center (Sharp), located in Chula Vista, California began considering options for their outdoor area lighting needs. Due to the excitement surrounding Solid State Lighting (SSL) Sharp had high hopes for a "perfect" Light Emitting Diode (LED) solution for their outdoor area lighting, specifically their parking lots, entrance roadways and parking structure.

In collaboration with Sharp, San Diego Gas & Electric selected and arranged for the installation of new LED lighting in a parking structure to replace existing metal halide (MH) fixtures. It was also agreed to provide LED luminaires for an entrance roadway and a parking lot to replace existing high pressure sodium (HPS) fixtures.

Realizing that the LED technology landscape was in a state of flux and that advancement was made by manufacturers continually, SDG&E®'s Emerging Technology Program (ETP) agreed to search and **identify the proper solution** for Sharp, seeking the customer's acceptance throughout product screening.

In July 2009, both SDG&E®'s Emerging Technology Program and the customer agreed on a LED luminaire that met Sharp's needs. After installation in August 2009, Sharp's reaction to the new LED parking structure luminaire was favorable. A side by side comparison of MH and LED technology was conducted with this selected product. **A lesson learned during this project was that an in situ assessment for an adequate length of time is a must before committing or gaining a customer's acceptance of a product.**

Project Background

PROJECT OVERVIEW

The Parking Structure LED Lighting Technology Assessment project was conducted as part of the Emerging Technologies Program of San Diego Gas & Electric Company (SDG&E®). 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." Emerging Technologies Associates, Inc. was retained by SDG&E® to manage the Parking Structure LED Lighting Technology Assessment project, develop project methodology, coordinate the participants and stakeholders and conduct the data collection and analysis for the project.

The Parking Structure LED Lighting Technology Assessment project studied the applicability of light emitting diodes (LEDs) in a parking structure application. At Sharp, seven MH fixtures were replaced with LED luminaires on one side of the parking structure while seven were left in place on the other side allowing for a side by side comparison of the light sources. The applicability of the technology was determined by light output and power usage, economic factors and customer satisfaction.

TECHNOLOGICAL OVERVIEW

At the time of this assessment, LED lighting in outdoor area lighting applications such as parking structures was gaining momentum because of the light source's ability to provide the required surface illuminance with improved uniformity and longer life using less energy than conventional lighting. The advancement of LED technology since the advent of white LED's presents some significant opportunities in outdoor area lighting which includes parking structures. "LED technology is rapidly becoming competitive with HID light sources for outdoor area lighting" *(source: www.netl.doe.gov/ssl DOE SSL LED Application Series: Outdoor Area Lighting).*

The most common light sources utilized to illuminate outdoor areas including streets, roadways, parking lots, parking structures and pedestrian areas are MH and HPS. The performance of these light sources is well documented with regard to lamp life and light characteristics. It is believed that a well-designed LED outdoor luminaire can provide at least comparable light characteristics as the traditional HID light sources in an efficient manner.

The U.S. 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 the cost remains a barrier to market entry. However, it should be noted that the costs for LED technology seems to be getting more competitive in the market place with each year that passes and technological advances are reaching outdoor area lighting applications.

MARKET OVERVIEW

The development of LEDs for the outdoor area lighting niche represents a major breakthrough in energy efficiency advancement because this application normally (66%) involves high wattage HID fixtures. HID lighting has an installed base of 3.1 million parking lot/garage/structure luminaires nationally. Currently, the market penetration of LEDs in this sector is estimated at 0% because LED products for this application have only recently become available. Market penetration is expected to increase, as lamp efficacy rises. [1] Additionally, cost and customer confidence in the quality and life expectancy will be barriers to market adoption.

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 installed base of parking lot/garage lighting fixtures of 3.1 million units results in California having an estimated installed base of 260,400 of such fixtures. Assuming SDG&E® service territory equates to approximately **7%** of California's total installed base (based upon statistics located at http://www.ecdms.energy.ca.gov/elecbyplan.aspx data found in Appendix B), it is estimated that SDG&E® has an installed base of 18,228 parking lot/garage/structure fixtures in its service territory. 100% market penetration would equate to approximately 130 GWh reduction in electricity use. Realistically, market penetration will most likely not ramp up until the high first cost barrier of LED luminaires is overcome. **Assuming 0.5% market penetration each year would result in an electricity savings of approximately 650 MWh annually** in SDG&E® service territory. **This translates into 156.2 kW of reduced demand using 4,165 annual operating hours** (assumed to be equal to hours stated in street light LS-2 Rate) for outdoor area lighting in SDG&E® service territory.

[1] Navigant Consulting, Inc. (2008). "Savings Estimates of Light Emitting Diodes in Niche Lighting Applications."

Project Objectives

The objectives of this project were to examine electrical, lighting, and economics of LED lighting technology in an outdoor area application, specifically a parking structure, as compared to the traditional light source of MH. The potential electrical demand and energy savings were measured in terms of instantaneous system wattage. The parking structure operates 8,760 hours annually. Lighting performance was measured in terms of illuminance and Correlated Color Temperature (CCT) measured in Kelvin (K). Finally, the 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.

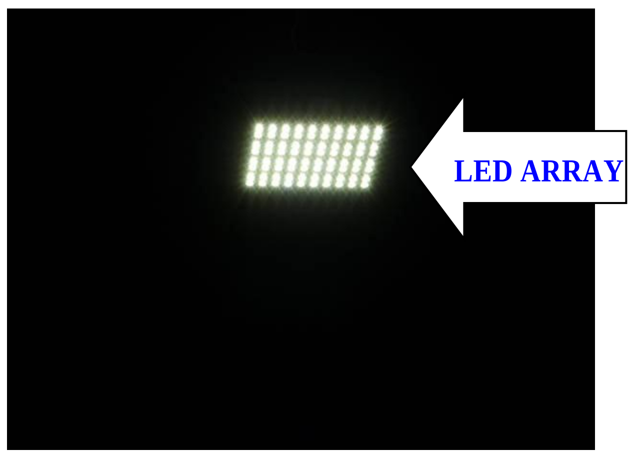


Figure 1: View of LED array in luminaire

Methodology

HOST SITE INFORMATION

Sharp Chula Vista Medical Center (Sharp) is a 343-bed non-profit hospital with the largest array of health care services in San Diego's South Bay. The facility is one of eight hospitals in the Sharp HealthCare system servicing San Diego County.

Sharp's outdoor lighting is either MH or HPS depending on the location of the fixture. The parking structure is lit by fourteen 250 W MH fixtures. There is only one level of parking in a non enclosed structure consisting of two separate parking areas, each lit by seven MH fixtures. Even though daylight is available from the sides of the structure, the lights remain on for all 24 hours each day. The purpose of the lights operating 24/7 is to provide sufficient lighting for employees, patients and guests to feel safe and secure. The fixtures are mounted at a height of 12 feet with variable spacing of 25 to 35 feet between fixtures. The lights operate 8,760 hours annually. The area does not have a surveillance camera. The customer's blended electric cost is $0.14 per kWh.

MEASUREMENT PLAN

A measurement plan was developed to measure the lighting performance of each luminaire. Pre and post installation field visits were conducted. A data point grid was used to collect the illuminance for each light source. The CCT was recorded directly below the luminaire. The light characteristic data for each application is in Appendix A. Instantaneous electrical power data for each light source was collected utilizing a Fluke 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: Fluke 322 meter

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The parking structure lighting consisted of fourteen 250 W MH fixtures. There is only one level of parking in a non enclosed structure. Even though daylight is available, the lights remain on 24 hours/day. Each MH fixture, consisting of the lamp and ballast, was measured and found to consume 291 W. The new LED luminaire consumed 141 W. This results in the LED luminaire using 52% less demand than the MH fixtures. Taking into account all the fourteen fixtures in the parking garage, the annual reduction of energy usage is 18,396 kWh or 52% less as shown in Table 3.

Table 3: Energy and Demand Savings

Luminaire	Number of Units	Fixture (W)	Energy (kW)	Total Energy (kWh)	Reduction (%)
250 W MH	14	291	4.1	35,688	
139 W LED	14	141	1.9	17,292	52

LIGHTING PERFORMANCE

For the assessment area, photopic illuminance and CCT readings were taken. The focus of this section is on the parking structure since photopic illuminance measurements were taken over a 50' X 70' area covering both traffic lanes and the parking stalls between three parking structure MH light fixtures with variable spacing. As can be expected in any field assessment, there were some issues affecting the desired homogenous area for the assessment. In this case the variable spacing does not provide for an accurate photopic illuminance uniformity values.

A side by side comparison of MH and LED technology was conducted with the selected LED Luminaire. Figures 2, 3 and 4 illustrate the difference in light source performance.

Figure 2: Side by side comparison of the technologies

Figure 3: Metal Halide lane (left) vs. LED lane (right)

Illuminance levels were measured on a 10’ X 10’ grid. The maximum and minimum illuminance levels were measured for each light source. The ratio of these two values is known as the uniformity ratio. The Illuminating Engineering Society of North America recommends a minimum light level of one foot-candle and a maximum uniformity ratio for parking structures of 10:1. Table 4 contains the photopic illuminance data and uniformity ratios. It is evident that neither light source meets the recommended maximum uniformity ratio.

Table 4: Photopic Illuminance Results

Luminaire	Grid Points Illuminated (%)	Average Illuminance (fc)	Max Illuminance (fc)	Min Illuminance (fc)	Avg-to-Min Uniformity	Max-to-Min Uniformity	CCT (K)
MH	100	1.08	5.04	0.05	22:1	101:1	3,860
LED	100	5.52	21.15	0.13	31:1	163:1	6,280

Note: An illuminated grid point had a photopic illuminance of 0.05 fc or higher

ECONOMIC PERFORMANCE

It is important to note that the cost and equipment assumptions made in this section apply only to Sharp Chula Vista Medical Center (Sharp). Sharp was assessing the replacement of high wattage HID MH light sources. Therefore readers should consider their specific variables such as maintenance, energy, luminaire/lamp costs and type of light distribution before drawing any conclusions about the cost effectiveness of LED luminaires. For LED 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. *The assumptions for LED life expectancy in this project is based upon 50,000 hours as per the United States Department of Energy website (source:* http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds.pdf)

1. Energy Cost Estimates

The energy cost is based upon the Sharp's blended rate of $0.14 per kWh. Sharp's parking structure operates 8,760 hours annually. Table 5 provides the energy cost and savings estimate assuming all the fourteen fixtures in the parking were converted from the base case MH HID to the new LED luminaires.

Table 5: Energy Cost Savings

Luminaire	Number of Units	Power (W)	Energy (kWh)	Annual Energy Cost ($)	Energy Cost Savings ($)
250 W MH	14	291	35,688	4,996	-
139 W LED	14	141	17,292	2,421	2,575

The simple payback calculations for a retrofit and new construction scenario considered the total investment cost and energy savings for the LED. In this project, the LED simple paybacks are shown in Tables 6 and 7. Table 8 provides the maintenance savings derived based upon the costs provided by Sharp. Table 9 provides the analysis of the payback for a retrofit scenario when maintenance savings are included. Maintenance costs were provided by Sharp's Director of Engineering.

Table 6: Retrofit Simple Payback Based Upon Energy Savings

Luminaire	Number of Units	Product Cost ($)	Installation Cost ($)	Total Investment ($)	Energy Cost Savings ($)	Simple Payback (yrs)
250 W MH	14	N/A	N/A	-	-	
139 W LED	14	14,630	2,400	17,030	2,575	6.6

Table 7: Simple Payback - New Construction

Luminaire	Number of Units	Product Cost ($)	Installation Cost ($)	Incremental Cost ($)	Energy Cost Savings ($)	Simple Payback (years)
250 W MH	14	4,200	2,400	-	-	
139 W LED	14	14,630	2,400	10,430	2,575	4.1

Table 8: Annual Maintenance Savings with LEDs

Light Source	Life Expectancy (years)	Labor ($)	Lamp Cost ($)	Disposal Fee ($)	Total Maintenance Cost ($)	Annual Maintenance Cost ($)	Annual Maintenance Cost Savings ($)
Metal Halide	2	30	30	4.50	64.50	32.25	-
LED	6	30	104.50	7.50	142.00	23.65	8.60

The disposal fees were obtained from City of San Diego Environmental Services Department. To derive annual maintenance cost savings, the total maintenance cost was divided by the life expectancy of the light source.

Table 9: Payback - Retrofit (including Maintenance savings)

Luminaire	Number of Units	Total Investment ($)	Annual Maintenance Cost ($)	Annual Maintenance Savings ($)	Energy Cost Savings ($)	Total Annual Savings ($)	Payback (years)
250 W MH	14	-	452	-	-		
139 W LED	14	17,030	331	121	2,575	2,696	6.3

Note: Installation cost assumed to be the same

2. Luminaires and Lamp Life

This report uses 50,000 hours as the LED life expectancy, per the DOE website (source: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds.pdf).

The manufacturer of the LED luminaires assessed in this project claim life expectancies greater than 50,000 hours. 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.”

In this project, the LED life is approximately 6 years which is shorter than the payback period when maintenance is included in the economic analysis indicating that the LED luminaire will not provide the appropriate payback to justify as a solution. ***This is a conservative approach due to the unproven life of LED products and does not indicate that LEDs are not a viable option to consider.***

Actual performance data documenting the life of LED luminaires does not yet exist due to the relative infancy of LED technology for general illumination applications such as parking structure lighting. While LED technology appears to be a viable option for parking structure 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 which has not undergone proper testing (i.e. LM 79, LM 80). The DOE LED Application Series: Outdoor Area Lighting Fact Sheet contains Design and Specifications Considerations:

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/outdoor_area_lighting.pdf

3. Life Cycle Cost Analysis

Even though life cycle cost analysis was not part of the scope of this project, 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, 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 LED luminaires 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.***

Conclusion

This assessment project demonstrated that properly designed LED luminaires can provide energy savings up to 52% without compromising light characteristics required for parking structure applications.

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

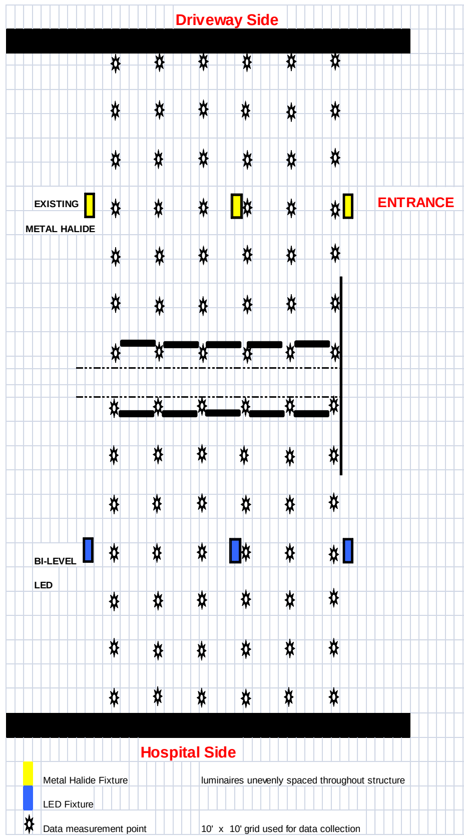
While the results of this project attest to the leaps in technological enhancements of LED lighting technology, the high first cost required to retrofit outdoor lighting applications including parking structures with LEDs will be the main barrier to significant market adoption. When using 50,000 hours as the expected life of the LED luminaire, the significant energy savings and reduced maintenance costs do not adequately offset this high initial first cost. Performance of LEDs combined with growing market acceptance of their higher performance versus traditional outdoor area light sources may provide early adopters the impetus to invest in the emerging technology.

Due to the unproven long life of LEDs, economic and reliability claims are based on the best available information from the manufacturer and DOE reports. The commercial viability of LED technologies is dependent on many factors but is likely to increase in the future as efficacies improve and luminaire costs decrease. The payback periods are also sensitive to product costs and the installation specific maintenance and electrical costs. In addition, these LED luminaires are applicable to many other outdoor lighting applications.

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 a technology, readers should conduct their own pilot or mini assessment of the available options to determine the economic feasibility of their particular project.

Appendix A

Data Collected for Parking Structure



			WALL				
	0.16	0.46	0.5	0.58	0.36	0.26	
	0.54	0.65	0.97	1.25	0.72	0.91	
M	1.2	0.96	2.05	2.91	1.83	1.59	
	1.8	0.9	2.7	5.04	1.98	2.19	**ENTRANCE**
H	1	0.63	1.75	2.45	1.61	1.74	
	0.4	0.34	0.53	0.68	0.78	0.06	
	0.19	0.16	0.17	0.22	0.18	0.05	
		OPEN	**AREA**				
	0.43	0.29	0.42	0.32	0.4	0.13	
	1.1	0.53	2	2.23	4.15	2.8	
L	8.4	4.66	9.15	11.3	10.45	16.4	
E	17.8	4.6	16.86	21.15	8.7	21.8	
D	14.8	5.07	10.3	8.4	10.1	7.65	
	2.6	0.45	1.35	1.7	0.55	1.25	
	0.18	0.23	0.26	0.23	0.35	0.5	
			WALL				

Appendix B

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**