SAN DIEGO STATE UNIVERSITY

LED Pathway Bollard

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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 Nate Taylor (NTaylor@semprautilities.com) as the Project Manager. Bill Lekas, Engineer, Physical Plant, was the contact and project manager for San Diego State University (SDSU). 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 SDSU 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

CFLs Compact Fluorescent Lamps

DOE Department of Energy

DR Demand Response

EEBI Energy Efficiency Business Incentives

ESB Energy Savings Bid

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

GHG Greenhouse Gas

HID High Intensity Discharge

HPS High Pressure Sodium

kW Kilowatt

kWh Kilowatt hours

LCCA Life Cycle Cost Analysis

LED Light Emitting Diode

PIER Public Interest Energy Research

SDG&E San Diego Gas & Electric

SDSU San Diego State University

SSL Solid State Lighting

W Watts

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Executive Summary

SDG&E® was interested in demonstrating LED technology for pathway lighting applications. San Diego State University (SDSU), a renowned green campus, agreed to participate in an assessment to determine the viability of LED bollards for their campus. This project demonstrated the illumination and energy savings potential of LED bollard pathway lights as compared to the traditional HID lighting system.

Due to their desire to become a "sustainable and green" campus and growing concern with increased energy costs, SDSU was interested in finding alternative solutions for their lighting systems campus-wide. Their Green Campus Interns identified LED pathway lighting as a potential solution that required further validation. SDSU wanted to ensure the selected LED luminaire met the requirements of occupant safety, equivalent light quality, and dimmability. This project consisted of replacing nine 75-watt HID pathway lights with 21-watt LED pathway lights. SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage the project, coordinate the participants and stakeholders, and conduct the data collection and analysis for the project.

This project proved in favor of LED bollards as a more efficient lighting solution for pathway lighting applications than HIDs. An estimated electrical energy and demand savings of 76% was achieved. The additional cost of the dimming feature, approximately $135 per luminaire, proved to provide incrementally insignificant energy cost savings making it difficult to financially justify. The simple payback was calculated for both new construction and retrofit scenarios. The results of these are shown in Tables 1, 2, and 3, respectively.

Table 1: Electrical Energy and Demand Savings

Lamp/Luminaire	System Wattage (W)	Operating Hours	Number of Units	Energy (kWh)	Demand (kW)	Savings (%)
HID* (75W)	88	4,234	9	3,353	0.79	-
LED (21W)	21	4,234	9	800	0.19	76

* *Base Case*

Table 2: Simple Payback – New Construction

Lamp/Luminaire	Cost/Unit ($)	Total Incremental Cost ($)	Number of Units	Total Incremental Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
HID* (75W)	895	-	9	-	3,353	0.16	537	-	-
LED (21W)	1,036	141	9	1,269	800	0.16	128	408	3.1

* *Base Case*

Table 3: Simple Payback – Retrofit

Lamp/Luminaire	Cost/Unit ($)	Number of Units	Total Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
HID* (75W)	20	9	180	3,353	0.16	537	-	-
LED (21W)	1,036	9	9,324	800	0.16	128	408	22.4

* *Base Case*

The results of this project will assist numerous facility managers, building owners, designers, municipalities, governmental agencies and developers across the country when considering LED bollard technology as an option for pathway lighting applications. It will enable them to meet their energy efficiency goals while maintaining lighting requirements and safety. Individual facility requirements as well as economic considerations may directly impact the outcome of similar demonstration projects.

Introduction

With the continued advancement of LED light sources and published claims that LEDs have a longer lamp life than traditional sources, there is an interest in determining the validity of LEDs as a solution in numerous outdoor lighting applications, including pathway lights. Due to their desire to become a "sustainable and green" campus and growing concern with increased energy costs, San Diego State University (SDSU) was interested in finding alternative solutions for their pathway lighting systems campus-wide. In collaboration with San Diego Gas & Electric (SDG&E®), SDSU agreed to participate in an assessment to determine the viability of LED pathway lighting. The goals of this project were to demonstrate the potential of LED pathway lights as a viable replacement lighting solution and determine the energy savings potential provided by LED pathway lights as compared to the HID base case.

SDSU is part of the California State University system and located in San Diego, California. Their Green Campus Interns identified LED pathway lighting as a potential solution which required further validation. This project consisted of replacing nine 75-watt (nominal) HID pathway lights with 21-watt LED pathway lights. SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage the project, coordinate the participants and stakeholders, and conduct the data collection and analysis for the project.

The results of this project will assist numerous facility managers, building owners, designers, municipalities, governmental agencies and developers across the country when considering LED bollard technology as an option for pathway lighting applications meeting their energy efficiency goals while maintaining the desired high quality illumination. By doing so, the hope is to achieve rapid adoption of LED bollard technology.

Project Objectives

The SDG&E® ETP conducted the LED Pathway Bollard project with the following objectives:

- determine viability of LED solution for pathway lighting applications
- determine the energy savings potential of LED bollard technology as compare to the base case HID technology
- determine the cost effectiveness of dimming as a viable “add on” to achieve deeper energy savings

Project Background

TECHNOLOGICAL OVERVIEW

Bollards are normally used to light common areas, pathways, and sidewalks. Traditionally, metal halide, high pressure sodium (HPS), or compact fluorescent lamps (CFLs) have served the purpose. The performance of these light sources is well documented with regard to lamp life and light characteristics. It is believed that LEDs could provide comparable or better quality of lighting than traditional sources while reducing energy consumption. Moreover, LEDs could be used for dimming, providing even greater savings. [1]

At the time of this assessment, LED lighting in outdoor area lighting applications such as pathway 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. Per the DOE SSL site, "LED technology is rapidly becoming competitive with high-intensity discharge (HID) light sources for outdoor area lighting." (Source: www.netl.doe.gov/ssl DOE SSL LED Application Series: Outdoor Area Lighting).

LEDs are particularly advantageous in outdoor lighting applications because they offer extremely long lifetimes, are directional light sources that limits light pollution and light trespass, are highly efficacious, function well in cold temperatures, are greatly resilient to vibration, and are able to provide a high quality light. [2] These key features of LEDs can prove useful for pathway lighting application since safety and reliability is of huge concern in this application.

The California Energy Commission's Public Interest Energy Research (PIER) Program sponsored the development of a bi-level LED bollard. CLTC, in close partnership with Gardco Lighting (Philips Group brand) developed the Bi-level Smart LED Bollard which uses high quality LED and microwave occupancy sensors to both efficiently light the pathway and further reduce energy consumption during unoccupied periods. [3]

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 the cost remains a perceived 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.

[1] http://cltc.ucdavis.edu/content/view/667/353
[2] Navigant Consulting, Inc. (2011). "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications."
[3] http://cltc.ucdavis.edu/content/view/667/353

MARKET OVERVIEW

The development of LEDs for the outdoor area, especially pathway lighting niche represents a major breakthrough in energy efficiency advancement because this application normally involves high wattage HID fixtures. Pathway lighting faces unique challenges concerning their lighting. Public safety concerns demand that lamps produce a high quality light with a low probability of failure. LEDs are becoming a popular option in pathway lighting applications as their long lifetime helps facility managers, building owners, designers, municipalities, governmental agencies and developers reduce costly lamp replacements. Some decision makers also view LEDs relatively high CRIs as welcome replacements for the poor quality of light that some incumbent technologies emit. [4]

The advancement of LED technology since the advent of white LEDs presents some significant opportunities in pathway lighting. However, due to the uniqueness of this niche market, there exists virtually no market data lending itself to calculate the impact of LEDs being adopted.

PROGRAMS

SDG&E® offers various programs and services for businesses to promote market adoption help lower their energy usage and manage costs. Some of their energy-savings programs include rebates, incentives, on-bill financing, and Demand Response (DR).

Rebates are the easiest way for businesses to earn money on energy-efficient purchases. With SDG&E's Energy Efficiency Business Rebates program, businesses can earn cash rebates with the purchase of new energy-efficient equipment such as lighting, refrigeration, ventilation, food service and more. Through its Energy Efficiency Business Incentives (EEBI) and Energy Savings Bid (ESB) programs, SDG&E® offers cash incentives for customers who replace existing equipment or install new high efficiency equipment. On-Bill Financing offers eligible businesses zero-percent financing for qualifying energy-efficient business improvements and works in conjunction with SDG&E's incentive and rebates programs. Moreover, with the DR programs, businesses that can lower their energy use during peak demand or shift their electricity use to off-peak hours are eligible to receive bill credits, payments or other incentives.

SDG&E® also offers online tools to help businesses manage energy use. Some of its online tools include kWickview, Benchmarking, Energy Waves, and Energy Challenger. There are also seminars, training workshops, and on-site energy consultations available as well. For more information on SDG&E® energy efficiency programs, it is recommended visiting the SDG&E® energy efficiency website: http://www.sdge.com/business/rebatesincentives/programs/allPrograms.shtml.

[4] Navigant Consulting, Inc. (2011). "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications."

Methodology

HOST SITE INFORMATION

San Diego State University (SDSU), part of the California State University system is located in San Diego, California. The base case lighting for pathway lighting application was HID bollards. A total of nine HID bollards with system wattage of 88 watts (75 watts nominal) were considered for this project. The pathway lights operate 4,234 hours annually (11.6 hours/day 365 days/year). SDSU's blended electric cost is $0.16 per kWh.

TITLE 24 REQUIREMENTS

SDSU wanted to ensure the new lighting met the requirements of occupant safety, equivalent light quality, and dimmability. SDSU also expressed an interest in the new lighting exceeding Title 24 requirements.

Section 147 of Title 24 outlines the requirements for outdoor lighting. The Allowed Lighting Power is calculated as the sum of the general hardscape lighting allowance, additional lighting power allowance for specific applications, and additional lighting power allowance for local ordinance. Since pathway lighting does not fall under specific applications, the Allowed Lighting Power is the sum of the general hardscape lighting allowance and additional lighting power allowance for local ordinance. Table 147-A outlines the measures for determining the general hardscape lighting power allowance.

TABLE 147-A GENERAL HARDSCAPE LIGHTING POWER ALLOWANCE

Type of Power Allowance	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Area Wattage Allowance (AWA)	0.036 W/ft^2	0.045 W/ft^2	0.092 W/ft^2	0.115 W/ft^2
Linear Wattage Allowance (LWA)	0.36 W/lf	0.45 W/lf	0.92 W/lf	1.15 W/lf
Initial Wattage Allowance (IWA)	340 W	510 W	770 W	1030 W

SDSU falls under Lighting Zone 3 and the Area Wattage Allowance is 0.092 W/ft^2. The general hardscape lighting power is determined as follows:

HID:

4 bollards x 88 watts = 352 watts / 1110 square feet (hardscape) = 0.317 W/sqft

LED:

4 bollards x 21 watts = 84 watts / 1110 square feet (hardscape) = 0.076 W/sqft

The additional lighting power allowance for local ordinance is outlined in Table 147-C below:

TABLE 147-C ADDITIONAL LIGHTING POWER ALLOWANCE FOR ORDINANCE REQUIREMENTS

ADDITIONAL LIGHTING POWER ALLOWANCE (W/ft^2) WHEN AVERAGE LIGHT LEVELS ARE REQUIRED BY LOCAL ORDINANCE.				
Required (horizontal foot-candles, AVERAGE)	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
0.5	0	0	0	0
1.0	0.004	0	0	0
1.5	0.024	0.015	0	0
2.0	0.044	0.035	0	0
3.0	0.084	0.075	0.028	0.005
4.0 or greater	0.124	0.115	0.068	0.045
ADDITIONAL LIGHTING POWER ALLOWANCE (W/ft^2) WHEN MINIMUM LIGHT LEVELS ARE REQUIRED BY LOCAL ORDINANCE.				
Required (horizontal foot-candles, MINIMUM)	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
0.5	0.004	0	0	0
1.0	0.044	0.035	0	0
1.5	0.124	0.115	0.068	0.045
2.0	0.164	0.155	0.108	0.085
3.0	0.164	0.155	0.108	0.085
4.0 or greater	0.164	0.155	0.108	0.085

Therefore, the total Allowed Lighting Power is 0.092. This was compared to the measured lighting power for the LEDs. The results showed that the LED luminaires were 17% better than Title 24 requirements.

MEASUREMENT PLAN

SDG&E® retained Emerging Technologies Associates, Inc. to manage the LED Pathway Bollard project, coordinate the participants and stakeholders, and conduct the data collection and analysis for the project. In collaboration with SDSU, SDG&E® selected and arranged for the installation of LED pathway lights as replacement for the HID base case. The 75-watt (nominal) HID pathway lights were substituted with 21-watt LED pathway lights.

Pre and post installation field visits were conducted. Electrical power data for the HID and the LED case was collected utilizing a Hobo Logger and CT. Meetings with SDSU were conducted to determine acceptability of the lighting quality. The acceptability of the technology was determined by SDSU's acceptance of the light levels, power usage and economic factors.

EQUIPMENT

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

Power reading:

HOBO U12 DATA LOGGER
ACCURACY: ± 2 mV ± 2.5% of absolute reading;
± 2 mV ± 1% of reading for logger-powered sensors

HOBO CURRENT TRANSFORMER
ACCURACY: ± 1%

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The base case consisted of nine HID pathway bollard lights with a measured demand of 88 watts. The retrofit LED pathway light's measured demand is 21 watts, resulting in a reduction in power of 76%. The results are shown in Table 4. Figure 1 shows the difference in the two technologies.

Table 4: Electrical Energy and Demand Savings

Lamp/Luminaire	System Wattage (W)	Operating Hours	Number of Units	Energy (kWh)	Demand (kW)	Savings (%)
HID* (75W)	88	4,234	9	3,353	0.79	-
LED (21W)	21	4,234	9	800	0.19	76

* *Base Case*

Figure 1: The base case HID (left) and LED solution (right).

ECONOMIC PERFORMANCE

It is important to note that the cost and fixture assumptions made in this section apply only to SDSU. SDSU was demonstrating the substitution of HID pathway lights. Readers should consider their specific variables 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 energy cost is based upon SDSU's blended rate of $0.16 per kWh. SDSU pathway lighting operates 4,234 hours annually. Table 5 provides the energy cost and savings estimate assuming all pathway lighting was converted from the base case HID to LED luminaires.

Table 5: Energy Cost Savings Achieved

Lamp/Luminaire	Number of Units	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Savings (%)
HID* (75W)	9	3,353	0.16	537	-	-
LED (21W)	9	800	0.16	128	408	76

* *Base Case*

The simple payback calculations considered the total investment cost and energy savings for the LED solution. The results are shown in Tables 6 and 7, respectively.

Table 6: Simple Payback – Retrofit

Lamp/Luminaire	Cost/Unit ($)	Number of Units	Total Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
HID* (75W)	20	9	180	3,353	0.16	537	-	-
LED (21W)	1,036	9	9,324	800	0.16	128	408	22.4

* *Base Case*

Table 7: Simple Payback – New Construction

Lamp/Luminaire	Cost/Unit ($)	Total Incremental Cost ($)	Number of Units	Total Incremental Product Cost ($)	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
HID* (75W)	895	-	9	-	3,353	0.16	537	-	-
LED (21W)	1,036	141	9	1,269	800	0.16	128	408	3.1

* *Base Case*

2. Luminaires and Lamp Life

This report uses 50,000 hours as the LED life expectancy, per the DOE website.[5] 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."

Actual performance data documenting the life of LED luminaires/lamps is evolving due to the relative infancy of LED technology for pathway lighting application. In this project, the LED life is approximately 12 years based on the annual operating hours. The payback period for retrofit and new construction, 22.4 and 3.1 years respectively, does not include maintenance in the economic analysis. This indicates that the LED luminaire will provide the appropriate payback to justify as a solution for a new construction scenario but not for a retrofit.

While LED technology appears to be a viable option for pathway lighting, LED product quality can vary significantly among manufacturers. 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 analysis (LCCA) was not part of the scope of this project, a full LCCA 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.

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

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. With the rapid advancement of LED technology, the pricing of the products may be reduced. Readers are encouraged to obtain current price quotes for HID, induction and LED lamps. Furthermore, each project's economic analysis will yield its unique set of results depending upon the project sponsors and site requirements.

Conclusion

This project validated that properly designed LED pathway lights can provide energy savings of 76% without significantly compromising the lighting performance required for pathway light applications. The energy savings realized were insignificant and did not justify the additional cost of the dimming feature, approximately $135 per luminaire. The LED pathway lights exceeded visual expectations resulting in Bill Lekas expressing an overwhelming endorsement and acceptance of LED pathway bollard technology as a desirable lighting solution.

While the results of this project indicate significant energy savings potential when LED pathway lighting is used instead of HID, readers are encouraged to complete a full life cycle cost analysis to gain the complete economic picture of a technological change out.

In this project, the LED life is approximately 12 years based on the annual operating hours. The payback period for retrofit and new construction, 22.4 and 3.1 years respectively, does not include maintenance in the economic analysis. This indicates that the LED luminaire will provide the appropriate payback to justify as a solution for a new construction scenario but not for a retrofit. It will help numerous facility managers, building owners, designers, municipalities, governmental agencies and developers across the country when considering LED technology as an option for pathway lighting applications, meeting their energy efficiency and greenhouse gas (GHG) emission reduction goals.

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.