Bi-Level Gas Station Lighting Technologies

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Preface

PROJECT TEAM

This project is sponsored by San Diego Gas & Electric’s Emerging Technologies Program (ETP), with Nate Taylor (NTaylor@semprautilities.com) as the project manager. Ron Stowers, owner, was the contact and project manager for Body Beautiful Car Wash Inc. (Body Beautiful). Daryl DeJean (daryldejean@gmail.com) of Emerging Technologies Associates, Inc. (ETA) provided technical consulting, technical 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, 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 Body Beautiful for their cooperation in the project. Without their participation, patience and cooperation allowing for a side-by-side comparison of various lighting technologies, this project would not have been possible. We would also like to thank SMUD and Rensselaer Polytechnic Institute's Lighting Research Center for their report and presentation on gas station under-canopy lighting projects. This project is corroborated by their previous outstanding work.

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Executive Summary

With various gas stations being located in close proximity, owners are usually competing for business. A common way to attract customers is to light up the canopy as brightly as possible, since the belief is that a well-lit under-canopy will more likely attract more customers. According to a report by Rensselaer Polytechnic Institute's Lighting Research Center, "An Evaluation of Three Types of Gas Station Canopy Lighting," the result has been a "brightness war between gas stations across America." [1] The conventional source of lighting in this application has been metal halide (MH) high intensity discharge (HID) which consumes a lot of energy. The most common fixture is the LSI Super Scottsdale recessed luminaire in which the lamp projects down into the glass refractor (non-cutoff) commonly providing illuminances exceeding 100 foot candles. Due to the significant energy savings potential, San Diego Gas & Electric's (SDG&E®) Emerging Technologies Program (ETP) desired to determine the viability of bi-level LED and induction lighting technologies in gas station and/or convenience store under-canopy lighting applications. Body Beautiful Car Wash Inc. (Body Beautiful) agreed to participate in this project at their Mobil gas station Mission Valley location in San Diego. The goal of the project was to determine the energy savings potential provided by bi-level LED and induction lighting sources as compared to the MH HID lighting system.

SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage the project, coordinate the participants and stakeholders, and conduct the analysis for the project. A side-by-side comparison was done with the conventional technology, MH HID, and the emerging technologies, LED and induction. Based upon pump island occupancy, the bi-level light sources would allow for the under-canopy lights to be further dimmed to a light level acceptable to the station's owner, allowing for electric load reduction.

The project is considered a demonstration showcase project. Such a project is described in the SDG&E Program Implementation Plan (PIP) for Emerging Technologies as:

"These possibly large-scale projects will expose measures to various stakeholders utilizing *in situ*, real-world applications and installations. Monitoring activities on demonstration showcases will be determined as appropriate …….. Demonstration showcases will contribute to increased measure awareness, market knowledge and reduced performance uncertainties for ETP stakeholders and IOU customers. "

For the purposes of this project, the evaluation, measurement and verification (EM&V) was established to provide minimal data and technical verification. Therefore, the established standard to adhere to the International Performance Measurement and Verification Protocol (IPMVP) was not required to be strictly followed.

The results of the demonstration showcase project are in favor of the LED and induction solutions as more efficient lighting solutions for gas station under-canopy lighting applications than MH. Body

[1] http://www.lrc.rpi.edu/programs/transportation/pdf/lightPollution/canopy.pdf

Beautiful opted for the LED solution due to the quality of the light output. By substituting MH with LED and induction luminaires, an electric energy and demand savings of 53% was achieved for the LED technology and 57% for induction. It should be noted that Body Beautiful is located at the entrance to a small strip mall and did not have original illuminance near the common 100 foot candles as stated previously. Instead, they maintained a much lower illuminance level. Although the goal of the project was to evaluate the bi-level feature of the LED and induction sources, the gas station pump islands were continuously occupied throughout the operating hours. Please see Table 6 in Appendix B for a 24-hr scenario.

Table 1: Energy and Demand Savings

Lamp	System Wattage (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Metal Halide *	288	2,904	8	6,691	2.30	-
LED	136	2,904	8	3,160	1.09	53
Metal Halide *	288	2,904	4	3,345	1.15	-
Induction	123	2,904	4	1,429	0.49	57

* *Base Case*

The simple payback was calculated and is shown in Table 2.

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)
Metal Halide *	30	8	240	6,691	0.17	1,137	-	-
LED	300	8	2,400	3,160	0.17	537	600	3.6
Metal Halide *	30	4	120	3,345	0.17	569	-	-
Induction	365	4	1,460	1,429	0.17	243	326	4.1

* *Base Case*

This project will assist gas station managers and owners when considering LED and induction technologies, and the applicability of bi-level operation, as an option for gas station under-canopy lighting. Not only will either solution assist in lowering operational energy costs, improving cash flow, they will address the goals of California's AB32 to reduce greenhouse gases through energy efficiency. Local site requirements, luminaire quality, light quality, economic considerations, and similar factors may directly impact the outcome of similar project projects. Therefore, readers are advised that each installation is unique and due diligence is recommended in selecting the appropriate technology specific to their needs.

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

- a survey of patrons may provide valuable insight into the impact of lighting on visual comfort, perceived safety, and desirability of "pulling into" a station
- impact of lighting on sales, gasoline as well as convenience store items
- impact of selected lighting technology and luminaire on glare and light trespass

Introduction

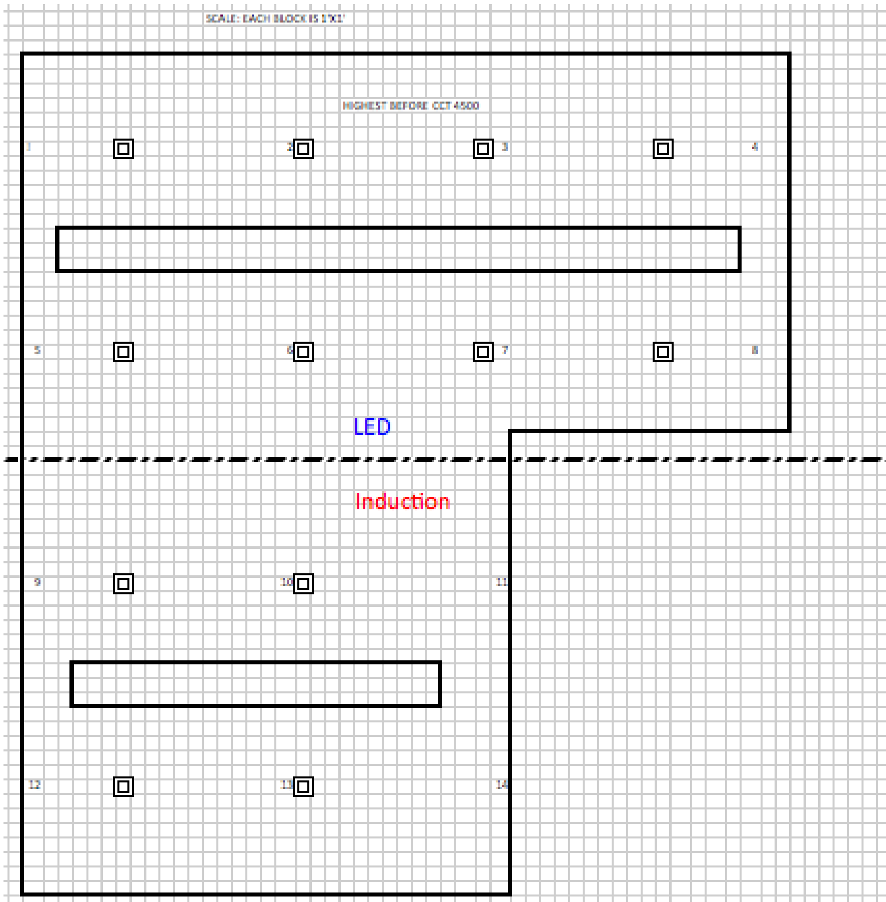
With various gas stations being located in close proximity, owners are usually competing for business. A common way to attract customers is to light up the canopy as brightly as possible, since the belief is that a well-lit under-canopy will likely attract customers. According to a report by Rensselaer Polytechnic Institute's Lighting Research Center[2], the result has been a "brightness war between gas stations across America."

With a desire to evaluate the potential of bi-level LED and induction lighting in a gas station and/or convenience store under-canopy lighting application, SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage this project, coordinate the participants and stakeholders, and conduct the analysis for the project. Body Beautiful Car Wash Inc. (Body Beautiful) agreed to participate in this project at their Mobil gas station Mission Valley location. The goal of the project was to determine the energy savings potential provided by bi-level LED and induction lighting technologies as compared to the metal halide (MH) high intensity discharge (HID) lighting system.

There are claims that LED and induction products offer various advantages over conventional lighting products. Manufacturers of these technologies claim that high quality lighting can be achieved by these sources at a fraction of the energy consumption, while providing longer life and ensuing reduced maintenance. In addition to determining the energy savings potential, this project aimed to validate these claims.

Body Beautiful was chosen due to the station having a unique under-canopy lighting configuration as shown in Figure 1 below, allowing for side-by-side comparison of the technologies. Eight LED luminaires replaced the MH HID source in one test area while four induction luminaires replaced them in another. Body Beautiful hoped that by opting for either LED or induction, in addition to energy cost savings, they could reduce their maintenance costs since LEDs and induction are presumed to have a longer life than MH HID light source. In addition to cost savings they were looking for a solution to improve the customer experience, meaning easier to read the pump and see their vehicles "true color" under the lighting. This was important since customers typically go through the car wash either before or after filling up with fuel using the lighting to "inspect" the car wash results.

[2] http://www.energy.ca.gov/title24/2005standards/archive/outdoor_lighting/documents/2002-03-27_workshop/public_comments/2001-12-28_Lighting_Researc.PDF



	BEFORE (fc)	LED (fc)
1	9.4	11.5
2	15.6	18
3	15.7	17.7
4	6.6	6.9
5	10.2	14.2
6	19.5	21
7	21.8	23
8	11.5	8.6
	BEFORE (fc)	INDUCTION (fc)
9	9.3	9.6
10	16.4	17.1
11	12	8.4
12	4.6	6.7
13	8.9	8.3
14	6.3	4.2
	CCT	CCT
	4000 - 4500	4000-4300

Figure 1: Gas station layout with dimensions and “before” and “after” CCT and Illuminance measurements

Project Objectives

The SDG&E® ETP conducted the Bi-Level Gas Station Lighting Technologies project with the following objectives:

- determine the energy efficiency and demand reduction potential of bi-level LED and induction for gas station under-canopy lighting as compared to MH lighting system, and contribution to California's AB32
- determine customer acceptance of bi-level lighting attribute at gas stations

Project Background

TECHNOLOGICAL OVERVIEW

At the time of this project, LED and induction lighting looked promising in gas station/convenience store lighting applications due to the potential for reduced energy consumption and longer life, compared to traditional sources. However, the perception is that the initial price of LED and induction technologies is much higher than conventional light sources, causing a significant barrier of entry into the market. This area has been dominated by MH HID source due to its ability to provide the desired lighting at a much less first cost. While this has been true in the past, recent prices of LED and induction solutions have become acceptable even in the retrofit scenario.

Today, the major barriers include the price myth, financial analysis based upon only energy efficiency and the lack of proper presentation of the solution to key decision makers. When the additional benefits of LED or induction technology are considered in the total cost of ownership, the solutions provide a compelling story to implement. And when a retrofit kit is used the value of reducing landfill waste as well as the embedded energy cost to produce luminaires may become increasingly important in the near future.

According to the U.S. Department of Energy, "induction lighting is one of the best kept secrets in energy-efficient lighting."

The advancement of LED technology since the advent of white LED's presents some significant opportunities for outdoor area lighting, such as gas station under-canopy lighting application. "LED technology is rapidly becoming competitive with high-intensity discharge (HID) light sources for outdoor area lighting"[3].

The most common light source utilized to illuminate gas station under-canopy is metal halide (MH). The performance of this light source is well documented with regard to lamp life and light characteristics. 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. It is believed that a well-designed LED outdoor luminaire can provide at least comparable light characteristics as the traditional high intensity discharge light sources in an efficient manner. 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. [4]

The metal halide lamps are rated for 10,000 hours. This is the point at which 50% of the lamps are predicted to have failed. Based upon independent lab test data, the predicted useful life of the LEDs will be at least 50,000 hours. It is important to note that the "useful life" of an LED light source is the point at which the light output is expected to have diminished by 30% - not when the LEDs fail.

[3] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/outdoor_area_lighting.pdf
[4] Navigant Consulting, Inc. (2011). "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications."

This demonstration showcase project clearly illustrates that both LED and induction retrofit kits for gas station under-canopy lighting are viable solutions. The results indicate that a well-designed retrofit kit that utilizes the existing luminaire housing and design to augment the heat sink of the retrofit kit is feasible. SDG&E® will monitor the performance and life of this project's lighting to determine if there are premature lighting level losses or failures since this is a retrofit.

MARKET OVERVIEW

In 2010 there were 7,276 gas stations in CA according to http://censtats.census.gov/cgi-bin/cbpnaic/cbpsect.pl. Using a station with twelve lamps and the results in Table 1 for converting from the more popular MH to LED, an electricity savings of 5296.5 kWh per station would be realized. With a 10% market adoption statewide, this would result in a 3,854 MWh savings.

By using estimates stating SDG&E® service territory equates to approximately 7.3% of California's total energy[5], we expect that SDG&E® has an installed base of 531 gas stations in its service territory. A 10% market adoption rate, would result in an electricity savings of approximately 281 MWh annually in SDG&E service territory. The demand reduction potential would be 96.8 kW.

It is believed that market adoption will ramp up once owners and managers are properly educated and made aware of projects such as this one. This education is required to overcome the price myth and to illustrate other attractive considerations that need to be incorporated into the financial analysis of the solutions.

[5] Based upon statistics located at http://www.ecdms.energy.ca.gov/elecbyplan.aspx data found in Appendix A

Methodology

HOST SITE INFORMATION

Body Beautiful was selected as the host site for this project due to the unique canopy configuration allowing for a side-by-side comparison of metal halide, LED and/or induction lighting technologies. The owner, was considering upgrading to more energy efficient lighting but was apprehensive about the claims and performance of LEDs. When approached by SDG&E® ETP, he was willing to participate and explore the highest performance and energy efficient lighting solution for his gas station and convenience store located adjacent to his car wash facility. Ron entrusted ETA, the project consultant, to select LEDs and induction that would not negatively affect his business. ETA selected retrofit kits in hopes that the project would accelerate market adoption due to the lower first cost, which when combined with all the other positive aspects of LED and induction lighting solutions, make retrofit kits particularly attractive.

The under-canopy lighting at Body Beautiful's Mobil gas station was metal halide. Test areas were chosen to allow for eight MH HIDs to be replaced with LEDs and four with induction. The under-canopy lighting operates on average 8 hours a day (2,904 hours annually) as recorded by the data loggers. The lighting operates daily approximately from 4:30 am until 7:00 am and from 5:30 pm to 11:00 pm, with seasonal variations. There are no automatic lighting controls. The lighting is controlled manually by the convenience store clerk. Body Beautiful's blended electric cost is $0.17 per kWh. Figure 2 shows the unique canopy layout and the comparison of the base case metal halide with the LED.

Figure 2: Side-by-side comparison of LEDs (left) and HID (right).

MEASUREMENT PLAN

The project team used a calibrated light meter to measure horizontal and vertical illumination levels before and after the retrofit. OnSet (Hobo) data loggers with current transducer were used to measure the amperage of each under-canopy lighting circuit.

Illuminance data was collected at the points illustrated in Figure 3.

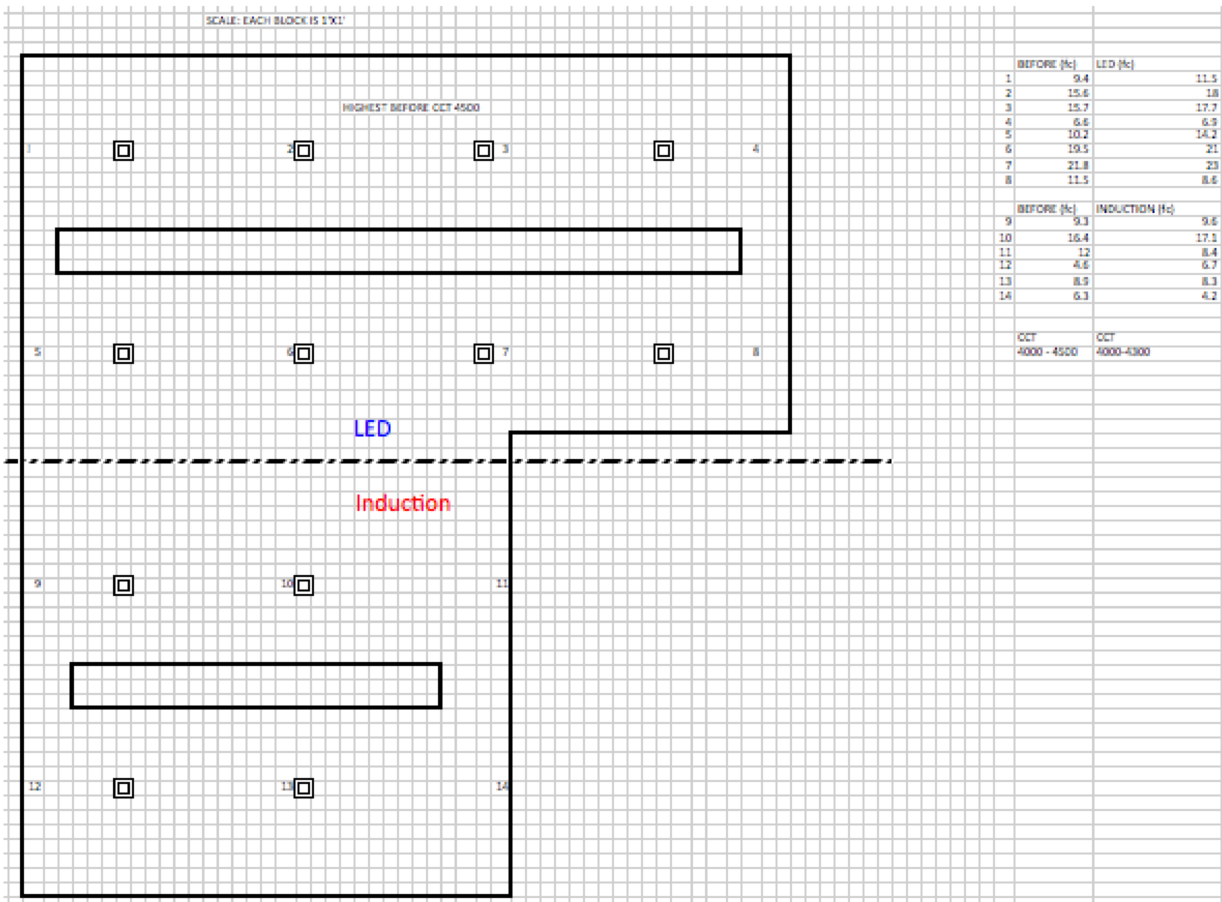


Figure 3: Gas station layout with dimensions.

INSTRUMENTATION

The following instruments were used to collect the project data. All equipment was calibrated in accordance with manufacturers' recommendations.

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%

Konica minolta chroma meter
Model CL-500
ACCURACY: ± 2.0%

Project Results

Figure 4: Side-by-side comparison of LED retrofit (left) and HID base case (right).

Figure 5: Side-by-side comparison of LED retrofit (left) and Induction retrofit (right).

ELECTRICAL ENERGY SAVINGS

The under-canopy lighting was originally lit by MH lamps. The lights operate 2,904 hours annually (8 hours per day). The MH lamp drew 288 W. The LED consumed 136 W resulting in 53% less power and induction consumed 123 W, resulting in 57% less power. The results are shown in Table 3.

Table 3: Energy and Demand Savings

Lamp	System Wattage (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Metal Halide *	288	2,904	8	6,691	2.30	-
LED	136	2,904	8	3,160	1.09	53
Metal Halide *	288	2,904	4	3,345	1.15	-
Induction	123	2,904	4	1,429	0.49	57

** Base Case*
*** Appendix C shows a comparison of 4 metal halides vs. 4 LEDs*

FINANCIAL ANALYSIS AND BENEFITS

It is important to note that the cost and fixture assumptions made in this section apply only to Body Beautiful and are for retrofit kits, not replacement luminaires. Body Beautiful was demonstrating the use of LEDs and induction as a substitute for MH light source. Therefore, readers should consider their specific variables such as maintenance, energy, luminaire costs and requirements for dimming before drawing any conclusions about the cost effectiveness of LED and induction luminaires for their own applications. Manufacturer claims, with regard to lifetime, should be carefully reviewed. See the section on “Luminaires and Lamp Life” for aspects that influence lifetime of LED and induction lighting.

1. Energy Cost Estimates

The energy cost is based upon the Body Beautiful’s blended rate of $0.17 per kWh. The Body Beautiful gas station under-canopy lighting operates 2,904 hours annually. This project focused on the replacement of the MH lighting under the gas station under-canopy with LED and induction lighting technologies. Table 4 provides the energy, energy cost and the cost savings for the base case MH and the new LED and induction luminaires.

Table 4: Energy Cost Savings Achieved

Lamp	Number of Lamps	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Energy Savings (%)
Metal Halide *	8	6,691	0.20	1,338	-	-
LED	8	3,160	0.20	632	706	53
Metal Halide *	4	3,345	0.20	669	-	-
Induction	4	1,429	0.20	286	383	57

** Base Case*

The simple payback calculations for both a retrofit and new construction scenario considered the total investment cost and energy savings for the LED and induction solutions. The results are shown in Table 5.

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)
Metal Halide *	30	8	240	6,691	0.17	1,137	-	-
LED	300	8	2,400	3,160	0.17	537	600	3.6
Metal Halide *	30	4	120	3,345	0.17	569	-	-
Induction	365	4	1,460	1,429	0.17	243	326	4.1

* *Base Case*

2. Luminaires and Lamp Life

This report uses the manufacturer's stated 100,000 hours as the induction life expectancy and 50,000 hours as the LED life expectancy. This is supported by the following publication:

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

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 payback period for retrofit and new construction does not include maintenance in the economic analysis. If a complete life cycle cost analysis were conducted the payback times would likely improve.

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 gas station under-canopy lighting. While LED technology appears to be a viable option for gas station under-canopy 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

Life cycle cost analysis (LCCA) was not part of the scope of this project, but is recommended prior to the implementation of lighting upgrades at other sites: There are many variables and considerations that are specific to each reader's situation. For example, labor, cost of materials, maintenance practices, cost of financing, inflation, energy rates, material cost, product life, and electricity rates should be determined for each specific project under evaluation.

Code and Standard Considerations

Many gas station owners use high illumination levels to attract customers – the brighter the better. Consequently, lighting power densities for fueling canopies can reach 3.5 Watt per square foot (W/ft^2) or higher. This is startling considering current California Title 24 (2008) energy standards only allow less than one watt per square foot for *office lighting!* Fortunately, recent advances in LED technology provide excellent opportunities to save energy and yet still satisfy the station owners' desire for higher illumination levels. This project reduced the lighting power density (LPD), expressed in W/ft^2, from 1.77 and 1.38 W/ft^2 for the MH HID to 0.838 and 0.589 W/ft^2 for the LED and induction areas, respectively. This is over a 50% reduction in LPD.

Exterior lighting allowances in California vary by Lighting Zones (LZ). Per Table 10-114-A of Title 24, gas station under-canopies would fall under Lighting Zone 3, requiring medium ambient illumination.

TABLE 10-114-A LIGHTING ZONE CHARACTERISTICS AND RULES FOR AMENDMENTS BY LOCAL JURISDICTIONS

Zone	Ambient Illumination	State wide Default Location	Moving Up to Higher Zones	Moving Down to Lower Zones
LZ1	Dark	Government designated parks, recreation areas, and wildlife preserves. Those that are wholly contained within a higher lighting zone may be considered by the local government as part of that lighting zone.	A government designated park, recreation area, wildlife preserve, or portions thereof, can be designated as LZ2 or LZ3 if they are contained within such a zone.	Not applicable.
LZ2	Low	Rural areas, as defined by the 2000 U.S. Census.	Special districts within a default LZ2 zone may be designated as LZ3 or LZ4 by a local jurisdiction. Examples include special commercial districts or areas with special security considerations located within a rural area.	Special districts and government designated parks within a default LZ2 zone maybe designated as LZ1 by the local jurisdiction for lower illumination standards, without any size limits.
LZ3	Medium	Urban areas, as defined by the 2000 U.S. Census.	Special districts within a default LZ3 may be designated as a LZ4 by local jurisdiction for high intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels.	Special districts and government designated parks within a default LZ3 zone may be designated as LZ1 or LZ2 by the local jurisdiction, without any size limits.
LZ4	High	None.	Not applicable.	Not applicable.

LPD according to Current Title 24 LPD requirements for vehicle service station canopies is 1.358 W/ft^2 as indicated in Table 147-B.

TABLE 147-B ADDITIONAL LIGHTING POWER ALLOWANCE FOR SPECIFIC APPLICATIONS

All area and distance measurements in plan view unless otherwise noted.

	Lighting Application	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
WATTAGE ALLOWANCE PER SPECIFIC AREA (W/ft2). Use as appropriate provided that none of the following specific applications shall be used for the same area.					
	Building Facades. Only areas of building façade that are illuminated shall qualify for this allowance. Luminaires qualifying for this allowance shall be aimed at the façade and shall be capable of illuminating it without obstruction or interference by permanent building features or other objects.	No Allowance	0.18 W/ft^2	0.35 W/ft^2	0.50 W/ft^2
	Outdoor Sales Lots. Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non sales areas shall be considered hardscape areas even if these areas are completely surrounded by sales lot on all sides. Luminaires qualifying for this allowance shall be within 5 mounting heights of the sales lot area.	0.164 W/ft^2	0.555 W/ft^2	0.758 W/ft^2	1.285 W/ft^2
	Vehicle Service Station Hardscape. Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires qualifying for this allowance shall be illuminating the hardscape area and shall not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.	0.014 W/ft^2	0.155 W/ft^2	0.308 W/ft^2	0.485 W/ft^2
	Vehicle Service Station Canopies Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	0.514 W/ft^2	1.005 W/ft^2	1.358 W/ft^2	2.285 W/ft^2
	Sales Canopies Allowance for the total area within the drip line of the canopy.	No	0.655	0.908	1.135

Conclusion

Emerging Technologies Program projects such as this one provide valuable insights for deploying emerging technologies. The goals of the Bi-Level Gas Station Lighting Technologies project were met:

- the energy efficiency potential of bi-level LED and induction lighting for gas station under-canopy applications as compared to MH lighting systems, and respective contribution to California AB32 were successfully demonstrated
- customer acceptance of the lighting performance was exceptional.

This project suggests that LED and induction lighting may be viable solutions for lighting requirements in gas station under-canopy applications. For Body Beautiful's gas station under-canopy lighting, the LED and induction retrofit kit solutions appear to be viable options. In addition, these solutions are applicable to many other outdoor lighting applications such as parking structures and parking lot pole lighting. However, 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.

This project further validated and show that LED and induction luminaires can provide energy savings of 53% and 57%, respectively. It is believed these savings can be achieved without compromising the lighting performance required for gas station under-canopy applications. A future project is recommended to:

- survey of patrons may provide valuable insight as to the impact of lighting on visual comfort, safety, desirability of "pulling into" a station
- determine impact of lighting on sales, gasoline as well as convenience store items
- measure the impact of selected lighting technology and luminaire on glare and light trespass

It was not in scope of this project to consider a review of the lighting design, but rather a one-for-one replacement. It may be possible to achieve even more energy reductions when implementing a proper lighting design. Proper lighting design for outdoor lighting applications, such as under-canopy lighting addresses:

- Horizontal illumination
- Vertical illumination
- Glare
- Color Rendering Index (CRI)
- Correlated Color Temperature (CCT)
- Lighting distribution
- Efficacy (Lm/W)

- Cost of ownership

Based on the Illumination Engineering Society of North America's recommendation of 3 to 5 foot-candles for pump islands, [6] much greater savings can be accomplished with a lighting re-design. For example, selecting fixtures with fewer LEDs would reduce first cost, and thereby provide more savings and improve payback. Therefore, it is recommended that owners and managers engage a qualified lighting designer to ensure maximum benefits of their under-canopy lighting upgrade projects.

Although LED technology is steadily improving, there are an awful lot of questionable or suspicious products in the market. To assist owners and managers in identifying potential luminaire manufacturers, it is recommended reviewing the list of manufacturers on the following helpful links:

- ENERGY STAR (DOE SSL program / Energy Star: http://www.netl.doe.gov/redirect/
- Design Lights Consortium's (DLC): www.designlights.org
- PG&E's: http://www.pge.com/led/

Readers are encouraged to complete a life cycle cost analysis to gain the complete economic picture of a technological changeout. It is important to note that each situation is different. Prior to committing to a technology, readers should conduct their own due diligence 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 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, Design Lights Consortium (DLC) (www.designlights.org), and PG&E (http://www.pge.com/led/).

[6] The IESNA Lighting Handbook, Ninth Edition

Appendix A

SDG&E® Market Potential Calculations Reference

California Electricity Statistics & Data

ECDMS Energy Consumption Data Management System — The California Energy Commission

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

Electricity Consumption by Planning Area

Planning Area Description	Year	Total Usage *
Burbank, Glendale, and Pasadena	2005	3,394
Dept. of Water Resources	2005	8,283
Imperial Irrigation District	2005	3,232
Los Angeles Department of Water	2005	24,638
Other	2005	1,748
Pacific Gas and Electric	2005	101,460
Sacramento Municipal Utility District	2005	10,523
San Diego Gas & Electric	**2005**	**19,910**
Southern California Edison	2005	99,261
TOTAL		272,449

*All Usage Expressed in Millions of kWh

SDG&E® **7.3 %**

Appendix B

Additional energy and demand savings may be realized in 24-hour applications when the canopy is unoccupied. By dimming the LEDs and inductions approximately 4 hours a day (1,460 hours per year), the potential additional cost savings that may be achieved with LEDs range from $225 and $128 with induction. Potential results are shown below in Table 6.

Table 6: Energy Cost Savings with Dimming in 24-hour Applications

Lamp	System Wattage (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Additional Cost Savings with Dimming ($)
LED *	136	4,380	8	4,765	0.17	810	-
LED	136	2,920	8	3,177	0.17	540	-
LED (dimmed)	23	1,460	8	265	0.17	45	-
LED w/dimming function		4,380	8	3,442	0.17	585	225
Induction *	123	4,380	4	2,155	0.17	366	-
Induction	110	2,920	4	1,285	0.17	218	-
Induction (dimmed)	20	1,460	4	117	0.17	20	-
Induction w/dimming function		4,380	4	1,402	0.17	238	128

* *Without dimming*

Abbreviations and Acronyms

AB32 Assembly Bill 32

CALiPER Commercially Available LED Product Evaluation and Reporting

CCT Correlated Color Temperature

CRI Color Rendering Index

DLC Design Lights Consortium

DOE Department of Energy

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

HID High Intensity Discharge

IES Illumination Engineering Society of North America

K Kelvin

kW Kilowatt

kWh Kilowatt hours

LCCA Life Cycle Cost Analysis

LED Light Emitting Diode

Lm/W Lumens per Watt

LPD Lighting Power Density

LZ Lighting Zone

MH Metal Halide

MWh Megawatt hours

PG&E® Pacific Gas & Electric

SDG&E® San Diego Gas & Electric

SSL Solid State Lighting

W Watt

Glossary

AB32: Global Warming Solutions Act which makes the Air Resources Board (ARB) responsible for monitoring and reducing GHG emissions. It directed the California Air Resources Board to begin developing discrete early actions to reduce greenhouse gases while also preparing a scoping plan to identify how best to reach the 2020 limit.

Color Rendering Index (CRI): a measurement for how accurately a lighting source renders colors. CRI may be an important factor - especially in retail environments. CRI values range up to 100 with 100 considered to be excellent.

Correlated Color Temperature (CCT): the apparent color of a light source, units are in Kelvin. Exterior lighting sources range in appearance from orange to blue-white. CCT has a tremendous impact upon the appearance of the space being illuminated. For example: high pressure sodium lamps have a CCT of ~2100 K and are very orange in appearance. Many exterior LED products are blue-white in appearance and tend to have ratings of 6200 K (or even higher). Daylight has a CCT of approximately 5000K.

Cost of ownership: First cost for parts and labor plus cost for maintenance and energy.

Cutoff: The IES classifies luminaires according to their upward distribution of light. These classifications include: Full Cutoff, Cutoff, Semi-Cutoff and Non-Cutoff.

Glare: in simplified terms, glare is the light shining in your eyes that causes discomfort and impairs vision.

Horizontal illumination: the amount of light delivered to horizontal surfaces such as the ground or the top of a surface. In the United States, it is measured in units called foot-candles.

Illuminance: used to describe the specific light which comes off the surface whether off a filament, light bulb, lens, louver, tabletop, etc. Stated in foot candles.

Lighting distribution: the manner in which a fixture distributes the light produced by the source (e.g. lamps). The key is to select fixtures that deliver light where it is needed while minimizing glare and wasted light.

Lighting power density (LPD): maximum allowable lighting density permitted by the code, expressed in Watt per square foot (W/ft^2) for a given occupancy/space type.

Light trespass: light falling where it is not wanted or needed, i.e. spilled / obtrusive light.

Luminaire: Light fixture or lamp.

Luminous Efficacy (Lm/W): the amount of light (measured in lumens) divided by the total power consumed (watts). It is analogous to miles per gallon for cars.

LM79: This approved method describes the procedures and precautions for performing reproducible measurements of total luminous flux, electrical power, luminous intensity distribution and chromaticity of solid-state lighting (SSL) products for illumination purposes under standard conditions.

LM80: The purpose of LM-80-08 is to allow a reliable comparison of test results among laboratories by establishing uniform test methods. It addresses the measurement of lumen maintenance testing for LED light sources including LED packages, arrays and modules only.

Vertical illumination: the amount of light delivered to vertical surfaces such as walls or people. This is a critical element for safety since it helps drivers identify hazards. Vertical illumination is also measured in foot-candles.