LED
Theater Stage Lighting

ET11SDGE0005

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SDGE
A Sempra Energy utility®

Prepared by:

Emerging Technologies Associates, Inc.

Preface

PROJECT TEAM

This project is sponsored by San Diego Gas & Electric's (SDG&E®) Emerging Technologies Program (ETP), with Nate Taylor (NTaylor@semprautilities.com) as the project manager. Seema Sueko, Executive Artistic Director, was the contact and project manager for Mo`olelo Performing Arts Company (Mo`olelo) and 10th Avenue Theater. 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 Mo`olelo and 10th Avenue Theater 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
DOE	Department of Energy
ETA	Emerging Technologies Associates, Inc.
ETP	Emerging Technologies Program
kW	Kilowatt
kWh	Kilowatt hours
LCCA	Life Cycle Cost Analysis
LED	Light Emitting Diode
SDG&E®	San Diego Gas & Electric
SSL	Solid State Lighting
W	Watts

List of Tables

Executive Summary

San Diego Gas & Electric (SDG&E®) was interested in evaluating the potential of converting a theater's stage lighting entirely to LEDs. Mo`olelo, a San Diego based performing arts company, produces their shows at 10th Avenue Theater. In late 2010, Mo`olelo and 10th Avenue Theater agreed to collaborate with SDG&E® to pursue the concept of a complete LED stage lighting "makeover." The objectives of this project were to upgrade the theater lighting to state of the art, energy efficient theater lighting, compare the quality of LED lighting with the base case halogen, determine the energy savings potential provided by the LED solution and ensure that the selected LED solution met the theater's visual objectives.

The 10th Avenue Theater was selected as the perfect test site since it is a multi-use historic building that offered the challenge of meeting theater stage lighting needs. The project consisted of replacing fifteen 1,000-watt halogen lamps with 100-watt LED luminaires. SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage the project, coordinate the participants and stakeholders, and conduct the analysis for the project.

This project proved that LED technology provides an efficient, better quality lighting solution for theater stage lighting applications than halogen. An estimated electric energy and demand savings of 90% was achieved. The simple payback for new construction was calculated to be 10.4 years and 10.7 years for new construction and retrofit scenarios respectively. The results are shown in Tables 1, 2, and 3, respectively.

Table 1: Energy and Demand Savings

Lamp	Power/lamp (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Halogen*	1,000	780	15	11,700	15.00	-
LED	100	780	15	1,170	1.50	90

** Base Case*

Table 2: 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)
Halogen*	119	-	15	-	11,700	0.20	2,340	-	-
LED	1,575	1,456	15	21,840	1,170	0.20	234	2,106	10.4

** Base Case*

Table 3: 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)
Halogen*	69	15	1,035	11,700	0.20	2,340	-	-
LED	1,575	15	23,625	1,170	0.20	234	2,106	10.7

** Base Case*

This demonstration project will assist numerous theater owners and operators when considering LED technology as an option for theater stage lighting applications. It will contribute to both their energy efficiency and sustainability goals without sacrificing lighting quality. Individual theater requirements as well as economic considerations will directly impact the outcome of similar demonstration projects. Readers are advised that each installation is unique and due diligence is recommended 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:

- Evaluation of impact of LEDs on heat load and total reduction in cooling requirements

Introduction

Theaters primarily use halogen light sources to provide theater stage lighting. Halogen lamps offer various advantages including a narrow beam to concentrate the light resulting in a very clean bright light. Drawbacks associated with halogen lamps include extremely high bulb temperatures and the resulting increase in heat load adds to the space cooling needs. Halogen lamps also have high operating and maintenance costs.

In 2007, Mo`olelo Performing Arts Company (Mo`olelo) launched a greening initiative to explore how to create theater processes that don't cause long-term damage to the environment. Mo`olelo, a community-focused, socially conscious, Equity theater company based in San Diego, CA, produces their shows at the 10th Avenue Theater. Both Mo`olelo and 10th Avenue Theater were interested in exploring how to "green up" the venue.

SDG&E® was interested in evaluating the potential of converting a theater's stage lighting entirely to LEDs. Mo`olelo and 10th Avenue Theater agreed to collaborate with SDG&E® to pursue the concept of a complete LED stage lighting "makeover." The objectives of this project were to upgrade the theater stage lighting to state of the art, energy efficient theater lighting, compare the quality of LED lighting with the base case halogen, determine the energy savings potential provided by the LED solution and ensure that the selected LED luminaire met the theater's visual objectives.

The project consisted of replacing fifteen 1,000-watt halogen lamps with 100-watt LED luminaires. SDG&E® retained Emerging Technologies Associates, Inc. (ETA) to manage the project, coordinate the participants and stakeholders, and conduct the analysis for the project.

Project Objectives

The SDG&E® ETP conducted the LED Theater Stage Lighting project with the following objectives:

- upgrade the theater stage lighting to state of the art, energy efficient lighting
- identify potential LED solution for theater stage lighting applications
- perform a visual comparison of the quality of LED technology against traditional high power halogen technology in theater stage lighting applications
- validate manufacturer's claims regarding energy savings
- determine customer acceptance levels of LED technology
- determine the energy savings potential provided by the LED solution
- ensure that the selected LED luminaire met the theater's visual objectives

Project Background

TECHNOLOGICAL OVERVIEW

At the time of this assessment, LED technology in theater stage lighting applications was typically not considered although it was gaining momentum in studio lighting, i.e. television studios. This project focused on high brightness, theater lighting used to provide quality lighting for theater stage shows. Halogen is the most common source of theater lighting. Currently, many theaters use high-wattage halogen lamps to meet their lighting needs.

New LED lighting technologies have the potential to meet the needs of theaters in many visual applications previously met by halogen lighting systems. Manufacturers claim that high quality lighting can be achieved by LEDs at a fraction of the energy consumption, while providing longer life and ensuring reduced maintenance. It is believed that LEDs meet such light quality needs as high color rendition and contrast. LEDs provide lower operating cost and reduced energy usage. Currently, the low operating hours of theater lighting and initial high price of LED technology present a significant barrier of entry into the theater market.

Information from the US Department of Energy suggests LED technology is changing at a rapid pace such that, "commercial white LED device efficacies have increased from 100 lumens per watt in 2008 to as high as 124 lumens per watt in 2010."[1] Due to these rapid advances in this field, it is expected that even more robust LED products will be entering the market.

MARKET OVERVIEW

The advancement of LED technology since the advent of white LEDs presents some significant opportunities in theater stage 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.

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

Methodology

HOST SITE INFORMATION

Mo`olelo Performing Arts Company (Mo`olelo) is a community-focused, socially conscious, Equity theater company based in San Diego, CA. Mo`olelo produces their shows at the 10th Avenue Theater, a multi-use historic building. The theater stage lighting at 10th Avenue Theater was provided by fifteen fixtures of 1,000-watt (nominal) halogen lamps. The fixtures were mounted at a height of twenty feet with various spacing between the halogen fixtures, depending upon the current production. The theater lights operate 780 hours annually (15 hours a week). 10th Avenue Theater's blended electric cost is $0.20 per kWh.

MEASUREMENT PLAN

SDG&E® retained Emerging Technologies Associates, Inc. to manage the LED Theater Stage Lighting project, coordinate the participants and stakeholders, and conduct the analysis for the project. SDG&E® reviewed the selected luminaire by Mo`olelo and their lighting consultant. With a total of fifteen 1,000-watt halogen lamps installed in the theater, this demonstration project allowed for an ideal comparison of the base case with the LED solution. Stated power data for the halogen and LED solution was utilized to determine electrical energy and demand savings. To ensure visual acceptance, Mo`olelo and 10th Avenue Theater personnel participated in a qualitative survey. The team evaluated the post-retrofit lighting to determine end-user acceptance and ensure it maintained the stage lighting quality.

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The theater lighting consisted of fifteen 1,000-watt halogen lamps and operates 780 hours annually (15 hours a week). The LED luminaire consumed 100 watts which resulted in 90% reduction in power. The results are shown in Table 4.

Table 4: Energy and Demand Savings

Lamp	Power/lamp (W)	Annual Operating Hours	Number of Lamps	Energy (kWh)	Demand (kW)	Energy Savings (%)
Halogen*	1,000	780	15	11,700	15.00	-
LED	100	780	15	1,170	1.50	90

** Base Case*

ECONOMIC PERFORMANCE

It is important to note that the cost and fixture assumptions made in this section apply only to 10th Avenue Theater. Mo`olelo was demonstrating the one-to-one replacement of halogen light sources at 10th Avenue Theater with LEDs. Therefore, 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 10th Avenue Theater's blended rate of $0.20 per kWh and the theater lighting operates 780 hours annually. This project focused on replacing the halogen stage lighting in the theater with LED lighting technology. Table 5 provides the energy cost and savings for the base case halogen and the LED luminaire.

Table 5: Energy Cost Savings Achieved

Lamp	Number of Lamps	Energy (kWh)	Energy Cost/kWh ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Energy Savings (%)
Halogen*	15	11,700	0.20	2,340	-	-
LED	15	1,170	0.20	234	2,106	90

** Base Case*

The simple payback calculation considers only the product cost and energy savings for the LED solution. The results are shown in Tables 6 and 7, respectively.

Table 6: 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)
Halogen*	69	15	1,035	11,700	0.20	2,340	-	-
LED	1,575	15	23,625	1,170	0.20	234	2,106	10.7

** Base Case*

Table 7: 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)
Halogen*	119	-	15	-	11,700	0.20	2,340	-	-
LED	1,575	1456	15	21,840	1,170	0.20	234	2,106	10.4

** Base Case*

2. Luminaires and Lamp Life

For LED technology, a properly designed fixture is required, meaning electrically and thermally, to achieve the life expectancy. If the fixture has poor electrical or thermal design, the light source life is adversely affected resulting in a much shorter life. 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 does not yet exist due to the relative infancy of LED technology for theater lighting applications. In this project, the LED life is approximately 64 years which is greater than the payback period of 10.7 years when maintenance is included in the economic analysis. This indicates that the LED luminaire will provide the appropriate payback to justify as a solution.

While LED technology appears to be a viable option for theater 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.

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.

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 halogen and LED luminaires. Furthermore, each project's economic analysis will yield its unique set of results depending upon the project sponsors and site requirements.

A visual inspection of the LED lighting was conducted by the Mo`olelo's Executive Artistic Director and Theater Team, the 10th Avenue Theater and the SDG&E® Project Team. The purpose was to determine if the LED solution met the theater's expected light levels. The LED illumination was aesthetically pleasing resulting in Mo`olelo and 10th Avenue personnel expressing an overwhelming endorsement and acceptance of LED technology as a desirable stage lighting solution.

Conclusion

In this project, the LED life is approximately 64 years which is greater than the payback period of 10.7 years when maintenance is included in the economic analysis. This indicates that the LED luminaire will provide the appropriate payback to justify as a solution. However, since actual performance data documenting the life of LED luminaires does not yet exist due to the relative infancy of LED technology for theater stage lighting applications, readers are encouraged to complete a life cycle cost analysis to gain the complete economic picture of a technological change out.

This demonstration project validated that properly designed LED luminaires can provide energy savings of 90% without compromising the lighting performance required for theater stage lighting applications. There are many factors that may be unique per project and require careful consideration. It is recommended that 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.