Retail LED Lighting Assessment

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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. Malcolm Koll of Charles Koll Jewelers (Charles Koll) was the contact and project manager. Emerging Technologies Associates, Inc. (ETA) provided the overall coordination of all parties involved and finalizing the report.

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ACKNOWLEDGEMENTS

SDG&E® and ETA would like to acknowledge Malcolm Koll of Charles Koll Jewelers for assisting in reviewing the products and installation of the LED fixtures. Without his participation, this assessment project would not have been possible.

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Abbreviations and Acronyms

CCT Correlated Color Temperature

CIE Commission on Illumination

CLTC California Lighting Technology Center

CRI Color Rendering Index

DOE Department of Energy

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

FC Foot Candle

FT Foot/Feet

GWh Gigawatt hours

K Kelvin

kW Kilowatt

kWh Kilowatt hours

LED Light Emitting Diode

LPD Lighting Power Density

LPS Low Pressure Sodium

MH Metal Halide

MR Multifaceted Reflector

PAR Parabolic Aluminum Reflector

SDG&E® San Diego Gas & Electric

SSL Solid State Lighting

UTC University Towne Center

W Watts

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Executive Summary

San Diego Gas & Electric (SDG&E®) was interested in evaluating the potential of converting the display case and focal point lighting in a retail store entirely to LEDs. During 2007, Charles Koll Jewelers (Charles Koll), San Diego, California began their search for the "perfect" Light Emitting Diode (LED) solution for their display cases. By collaborating, SDG&E® and Charles Koll were able to pursue the concept of a complete lighting "makeover" in a retail showroom. Charles Koll was selected since it was a relatively small location yet offered the challenge of meeting display case, overhead, focal point and accent lighting needs. This is important since the test site allowed for a progressive assessment of LED technology and the interplay lighting applications to produce the desired lighting effects in a retail setting.

In addition to the key goal of the project, the assessment of energy savings, the project team had to keep in perspective the store owner's visual merchandising objectives which were to:

- improve the quality of the display case lighting
- create the right "atmosphere" in his store with accent lighting
- utilize the visual attributes of LED lighting to enhance the appearance of jewelry items

Quantitative and qualitative light and electric power measurements were taken throughout the project. As a result of this project, Charles Koll was able to reduce their energy consumption significantly (67%) for the entire showroom area while achieving better light quality throughout the showroom. The energy used in the display case lighting was reduced by 36% and electricity used for the focal point lighting went down by 80%. The simple payback for retrofitting the entire showroom with LEDs is 6.3 years. Tables 1 and 2 show these results.

Table 1: Energy and Demand Savings

		System Wattage (W)	Demand Savings (kW)	Annual Energy (kWh)	Energy Savings (kWh)	%
Display Case	Bi-pin Halogen (27.1 W/ft)	1,626	-	7,102	-	-
	LED (17.25 W/ft)	1,035	0.6	4,521	2,581	36
Focal Point	60 TOTAL Halogen MR16	3,600	-	15,724	-	-
	38 TOTAL LED PAR	713	2.9	3,115	12,609	80
Total Showroom	Base Case	5,226	-	22,826	-	-
	With LEDs	1,748	3.5	7,636	15,190	67

Table 2: Simple Payback for Showroom – Retrofit

Light Source	Initial Investment ($)	Installation Cost ($)	Total Investment ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	-	-	-	3,196	-	-
LED	10,400	3,000	13,400	1,069	2,127	6.3

* *Base case*

This assessment project was unique since it is considered the first such project. The project findings will assist numerous retailers across the country when considering LEDs as a new lighting retrofit option meeting their energy efficiency as well as visual merchandising needs.

Based upon the findings of this project, it is recommended that future projects consider working with designers involved in the retail market to gain a better understanding of the interactive nature of all lighting - ambient, focal point, perimeter, display case, etc., in visual merchandising.

Introduction

In response to an overwhelming interest in innovations in LED lighting technology for the retail merchant market segment, San Diego Gas & Electric's objective with this assessment was to:

- identify potential LED solution for the retail merchant market segment
- assess various manufacturers' products in 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 power incandescent technology in various applications, i.e. display case, focal point lighting, accent lighting etc.
- determine customer acceptance levels of the new LED technologies

Charles Koll selected and installed a linear LED retrofit product for the display cases. The California Lighting Technology Center (CLTC) provided the technical consulting to determine the performance of the linear LEDs. A report of findings on the display case LED lighting system was completed in summer 2008.

In collaboration with Charles Koll, SDG&E® agreed to expand the scope of work to include a complete "makeover" converting all showroom lighting to LED technology. Demonstration of potential LED direct replacement lamps were conducted beginning in June of 2008. Numerous LED manufacturers' product was tried during the next year. In June 2009, agreement was reached with the customer that a direct replacement lamp PAR lamp was the best solution. This required installing new overhead recessed downlight fixtures directly over each display case. The installation was complete in October 2009. Quantitative and qualitative lighting and electrical power measurements were taken for both pre and post installation.

Project Background

PROJECT OVERVIEW

The Retail LED Lighting Assessment project was conducted as part of the Emerging Technologies Program (ETP) 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." Project Management and Methodology was provided by Emerging Technologies Associates, Inc.

The Retail LED Lighting Assessment project studied the applicability of light emitting diodes (LEDs) in the retail merchant space. High wattage incandescent lighting used for display case as well as overhead and focal point lighting were replaced with new LED linear and LED PAR lamps at a retail jewelry store, Charles Koll Jewelers at their University Towne Center location. The applicability of the technology was determined by light output, energy and power usage, economic factors and customer satisfaction.

TECHNOLOGICAL OVERVIEW

At the time of this assessment, LED lighting in the retail merchant applications were gaining momentum because of the light sources' ability to provide greater control of light dispersion, greater maintenance savings and desire for higher quality light to accent product. This was particular true for the display case application. Currently, retail merchants use incandescent or fluorescent light sources to provide in-case and overhead lighting. Incandescent is primarily used to provide focal point lighting. Incandescent lights are used primarily because of they are inexpensive, are readily available in many sizes and intensities and because retailers have adapted to their light output and characteristics and have integrated the latter into their visual merchandising designs.

The LED PAR lamp portion of the project focused on high brightness, focal-point lighting used to provide quality lighting for customers to view their selected jewelry products. Focal-point lighting is the second most common type of lighting in retail display lighting, following linear fluorescent track lighting, which is used to provide accent or display case lighting.[1] Currently, in many applications focal-point lighting is accomplished with halogen MR16 lamps. Halogen MR16 lamps are used primarily for their "spotlight" ability, lower cost as compared to ceramic metal halide and the lack of other lamp options.

New LED lighting technologies have the potential to meet the needs of retailers in many in store design and visual merchandising applications heretofore met by incandescent and fluorescent lighting systems

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

at a fraction of the energy consumption, while providing longer life and ensuring reduced maintenance. It is believed that such light quality needs such as high color rendition and contrast can be coupled with reduced operating cost and reduced energy usage with LED's. Currently, the initial cost of LED technology is much higher than the cost of conventional light sources, causing a significant barrier of entry into the realm of retail lighting; traditionally low operating margins forces retailers to delay adoption of new technologies until large scale utilization of LED light sources forces down product prices.

At the time of this assessment, LED light source showed potential in the retail display lighting application because of their potential for extensive energy savings when compared to incumbent lighting technologies. Additional benefits specific to retail focal-point lighting include long operating life, lower maintenance and life-cycle costs, reduced radiated heat, minimal light loss, controllability, direction illumination, and adjustable color temperature when compared to traditional sources.[2] At this time, however, the initial cost of LED lamps in general is much higher than alternative light sources such as halogen MR16 lamps.

Information from the US Department of Energy suggests LED technology is changing at a rapid pace such that, "since 2002, commercial white LED device efficacies have increased from 30 lumens/W (DOE, 2006a) to about 100 lumens/W in 2008."[3] Due to these rapid advances in this field, it is expected that even more robust LED products will be entering the market which may permit direct one-for-one replacement scenarios as well as meet a broader base of customer investment criteria.

MARKET OVERVIEW

The advancement of LED technology since the advent of white LED's presents some significant opportunities in the retail lighting. "A high quality, energy-efficient lighting system can help add to a retailer's competitive advantage by attracting more customers and reducing operating costs, while directly helping the company's bottom line," according to IFCI, Paul Vrabel – Architectural Lighting Magazine March 2003.

A report by Navigant Consulting in 2002 estimates that lighting makes up approximately 22% of IOU kWh sales on a national scale. Using kWh sales figures from a 2006 study, the total consumption in SDG&E®'s service territory for lighting is calculated to be on the order of 4,093 GWh in 2002.[4] This study also provides values for kWh lighting figures within SDG&E®'s commercial sector only. A 2002 DOE study found that of the total commercial lighting in the United States about 12% is consumed by retail display areas resulting in an estimated energy savings potential within SDG&E® service territory

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

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

[4] Itron Inc., et al (2006). "California Energy Efficiency Potential Study".

of retail display lighting of around 491 GWh.[5] Although these figures are not exclusively for display case and focal-point retail display lighting using MR16 lamps (the estimate also includes accent lighting), the figures do give an idea of the significant potential that exists for savings.

The penetration of LEDs into the retail lighting display niche is of importance for energy efficiency measures because this application normally involves high-power, high-brightness fixtures. Currently, the market penetration of LEDs in the retail display sector is estimated at 0% because LED retail display products have only recently become available. Further market penetration is expected to increase, as efficacy increases. [6]

[5] Navigant Consulting, Inc. (2002). "U.S. Lighting market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate."

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

Project Objectives

The objectives of this project were to examine the electrical, lighting, and economic performance of LED lighting technology both in display cases and focal point lighting as compared incandescent lighting used in the retail market. The potential electrical demand and energy savings were measured in terms of instantaneous system wattage and estimated annual kWh usage was calculated utilizing this instantaneous system wattage and estimated annual hours of operation. Lighting power density was also calculated. Lighting performance was measured in terms of illuminance and CCT measured in Kelvin. Finally, economic performance was calculated as simple-payback for substitution in new installation or replacement scenarios. A payback taking into account lamp life-span, maintenance costs, in addition to electrical cost savings was also completed.

Figure 1: Charles Koll family crest behind display cases

Methodology

HOST SITE INFORMATION

Charles Koll is a specialty jewelry store located in Westfield UTC Mall in the heart of San Diego County. In November 2008, San Diego Gas & Electric's (SDG&E®) Emerging Technology Program (ETP) partnered with Charles Koll to conduct an assessment of the selected LED solution for their display cases. Due to the success and high lever of acceptance of the in-case lighting solution and interest of the store in converting the entire showroom to LEDs, SDG&E®'s ETP extended the project to identify a total LED solution for the retail jeweler's showroom.

Charles Koll Jewelers' showroom is a 1,000 square foot showroom lit by a track lighting system comprised of fifty-two 50 W halogen MR16 lamps for focal point lighting, two units of 50 W halogen MR16 lamps in a 2" recessed can for clerical work area, six units of 50 W halogen MR16 lamps for accent lighting and a display case lighting system comprised of bi-pin 50 W halogen lamps. There are 15 display cases, 48' in length yielding a total of 60 linear feet of in case display lighting. There are five 20W bi-pin halogen lamps per display case. In addition, there are three offices and a work area lit by fluorescent fixtures which were not included in the assessment.

The store lighting is operated for an average of twelve hours per day, 364 days per year for annual operating hours of 4,368 hours. The customer pays $0.14 per kWh. The space is conditioned by two rooftop heat pump units, one designated for the showroom area.

MEASUREMENT PLAN

ETA was retained by SDG&E® ETP to manage the Retail LED Lighting Assessment project, develop project methodology and coordinate the participants and stakeholders involved in the project. The California Lighting Technology Center conducted the lighting analysis for the display case phase. ETA conducted the electric power measurements for all phases and the light measurements for the focal point lighting phase. The data collected on the light characteristics are contained in Appendix A for the display case lighting and Appendix B for the focal point and accent lighting.

The project was a staged project completed in two phases:

- Phase I: Display Case lighting assessment
- Phase II: Focal Point and Accent lighting direct replacement

A measurement plan was developed to provide a consistent approach to measuring the lighting performance. A consistent methodology for data collection was important because it allows the demonstration team to quantify the effects of the installation. To help determine the impact of the new in case display LED lighting on customer comfort as well heat load reduction, the glass temperature was recorded. The owner felt this was important to ensure any new lighting measure also improved the comfort of his customers. The grid used to measure lighting performance and characteristics for both in case display lighting and the focal point lighting is shown below in Figure 2.

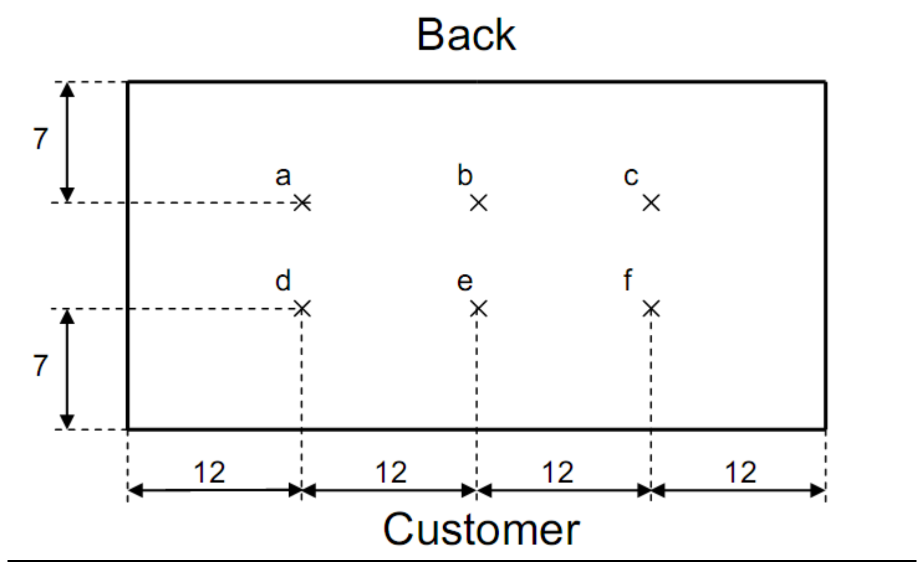


Figure 2: Data measurement points for both in display case and on top of display case

Electrical power data was collected utilizing the WattsUp? PRO meter. Throughout each phase of the project, the power data was easy to obtain since the new LED light source could be plugged directly into the WattsUp? PRO meter. Table 3 contains the data for the power for each light source.

Table 3: Power Measurements for Each Light Source

Light Source	Stated Power (W)	Measured Power (W)
Bi-pin linear display case lighting	27.1 (per ft)	27.1 (per ft)
LED linear display case lighting	15 (per ft)	17.3 (per ft)
MR16 halogen track lighting	50	60
LED PAR20	5	5.1
LED PAR30	15	16.2
LED PAR38	22	23.5

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:

WattsUp? PRO meter
Accuracy: ± 1.5%

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

To properly illustrate the demand and electrical energy savings, the results for each phase, display case, accent lighting and focal point lighting were assessed separately.

Phase I - Display Case Lighting Replacement:

The display case consisted of a total of sixty 20 W bi-pin halogen lamps. These were replaced with a total of 60 feet of linear LEDs. For each display case, pre-installation power equated to 108 W. Retrofit installation resulted in a power of 69 W per case. The linear LED in the display cases resulted in a 36% reduction in demand than the incumbent. An annual energy savings of 2,581 kWh was achieved. Table 4 provides the data reflecting such reductions.

Table 4: Energy and Demand Savings for ALL Display Cases

Lighting Power Density	System Wattage (W)	Demand Savings (kW)	Annual Energy (kWh)	Energy Savings (kWh)	%
Bi-pin Halogen (27.1W/ft) *	1,626	-	7,102	-	-
LED (17.25 W/ft)	1,035	0.6	4,521	2,581	36

* *Base case*

Phase II - Focal and Accent Lighting Replacement:

The existing track lighting was used to illuminate pictures, the store name and family crest of the owner, as well as provide focal point lighting for the display cases. A total of sixty halogen MR16 lamps were used as follows: six pieces for artwork, family crest and store name; two pieces over work station; and the remaining fifty-two pieces provide over the display case focal point lighting. Pre-installation power was 3,600 W and post LED PAR lamp installation power was 713 W. Table 5 provides the data reflecting the reductions.

Table 5: Energy and Demand Savings for ALL Focal Point and Accent Lighting

Light Source	Wattage (W)	Demand Savings (kW)	Annual Energy (kWh)	Energy Savings (kWh)	%
52 Halogen MR16 (50W)	3,120	-	13,628	-	-
28 LED PAR38 (22W)	658	2.5	2,874	10,754	79
2 Halogen MR16 (50W)	120	-	524	-	-
2 LED PAR30 (15W)	15	0.1	66	458	87
6 Halogen MR16 (50W)	360	-	1,572	-	-
8 LED PAR20 (5W)	40	0.3	175	1,397	89
60 TOTAL Halogen MR16	**3,600**	**-**	**15,724**	**-**	**-**
38 TOTAL LED PAR	**713**	**2.9**	**3,115**	**12,609**	**80**

LIGHTING POWER DENSITY

The lighting power density (LPD) was calculated for the showroom area according to the following equation:

$$Lighting\ Power\ Density \equiv \frac{Installed\ Watts\ (W)}{Site\ Area\ (ft^2)}$$

The installed watts included the wattage of the track fixtures which used MR16 lamps for both ambient and focal-point lighting. There were sixty 50 W halogen MR16 lamps in use in the Showroom area.

As seen in the tables below, through the use of LED Direct Lamp Replacement lamps the lighting power density for the showroom area was reduced by approximately 81% over the incumbent Halogen lamps as shown in Table 6.

Table 6: Lighting Power Density for Showroom

Light Source	Power – Showroom Lighting (W)	Area (ft^2)	LPD (W/ft^2)
Halogen MR16 (50W) *	3,600	1,000	3.6
LEDPower PAR Lamps	713 **	1,000	0.7

** Base case*
*** 28 PAR 38 (22W), 2 PAR 30 (15W) and 8 PAR 20 (5W)*

LIGHTING PERFORMANCE

Appendix A contains the data collected to determine lighting performance for the display case lighting. Appendix B contains the data collected to determine lighting performance for the focal point lighting. Appendix C contains expert discussion on light characteristics.

1. Correlated Color Temperature (CCT)

One of the requirements of the owner of Charles Koll for the new LED lighting system was that the product appearance remains the same when the product is within the case and when it is moved to the top of the case on top of the glass.

Correlated Color Temperature (CCT) is very important in the jewelry business. It plays an important role in providing “honest light.” The ability to provide lighting as close as possible to the CCT of daylight is very important. This is to ensure that the product maintains the same sparkle and brilliance regardless of the lighting conditions (in store versus daylight). The LEDs broader range of CCT is highly desirable in the retail jewelry market segment.

Figure 3: Display case with linear LED lighting system

To compare the light characteristics of the base case and the LED, illuminance and Correlated Color Temperature data was collected pre and post installation of the LEDs. Both illuminance and CCT measurements were taken using a Konica Minolta Chroma meter. Measurements were taken in a grid on the inside of the display case as well as the top of the case. The same grid was used for both sets of measurements.

One of the most critical criteria of visual design is color temperature. Retail designers understand and have incorporated into their work the psychological impact of light sources characteristics on the shoppers' buying decision. Warm light sources (i.e. lower color temperatures lamps) are associated with high-end retail applications, hotels and fine dining to created a sense of calm and comfort. Neutral and cool lights are for offices, supermarkets and fast food restaurants to create a high speed or faster moving atmosphere.

2. Color Rendering Index (CRI)

Color Rendering Index (CRI) is the measure of the quality of light color, developed by the International Commission on Illumination (CIE). Typically, the CRI of a lamp is found on an incandescent halogen, metal halide or fluorescent lamp's packaging or in the manufacturer's catalog. With LED's, CRI may not a good metric of light quality since it has been documented that LEDs with very low CRIs provide a superior "brightness" or vibrant appearance than equivalent incandescent sources.

As with color temperature, most retailers prefer light sources as close to daylight as possible. This ensures that customers remain satisfied with a product when they use products in environments outside of the store. As a result, it is important to utilize light sources with as high of a CRI as possible in retail applications when using traditional light sources. However, LEDs of a lower CRI may provide better appearances.

1. Honest Light

The owner of Charles Koll expressed his concern with the potential that “artificial” lighting could misrepresent the product that a customer purchased. His fear was that a customer would leave the store and become dissatisfied with the sparkle and brilliance of the product. In general terms, it is extremely important that product appearance must remain consistent whether in the store or in broad daylight. Additionally, the owner stated that the focal point lighting of the LED light source must compliment the case lighting to eliminate any different appearance of the product upon removal from the display case. As a result, the concept of “Honest Lighting” extends not only from the display case to the ambient store light, but also to daylight. He believes the current MR16 lighting failed to meet this requirement, however, the LED that he selected is far superior in providing honest lighting.

2. Intensity of Light

Adequate lighting intensity is an extremely important factor to consider in a retail jewelry store. Illumination on not only horizontal, but vertical surfaces helps to avoid dark spots and shadows in a space.

In this assessment of the focal point lighting, the MR16 provides a candlepower of 100 fc per lamp; the PAR38 LED selected by the store owner produced a maximum candlepower of 115 fc at the intersection of the center beam from two newly installed PAR38s. Intensity is required to properly illuminate the product once removed from the display case and viewed by a customer on the surface of the display case. Jewelry products are small and must be viewed under high intensity light.

3. Attractive and Unobtrusive Luminaires

Luminaires in recessed applications should not draw the attention of the customer away from the product which they are meant to purchase. As a result, fixtures should be discreet and unobtrusive, and when possible recessed into the ceiling. The owner stated that he designed his track lighting to be recessed so the customer would not easily notice the track fixtures hanging from the ceiling. This causes some limitations on the type of LED lamp could be used as a solution for the replacement of the MR16’s. Due to the directional nature of LEDs, the fixtures could easily be directed toward the objects to be illuminated due to the narrow soffit in which the track lights where installed. Some of the LED’s had elongated heatsink’s and stuck out of the track lights; they were rejected by the store owner.

Although the recessed track may be unique to Charles Koll, it illustrates the importance of proper design and the limited fixture selection currently available on the LED lamp market.

Figure 4: Unobtrusive light – recessed into the ceiling

4. Pools of Light and Multiples Point Source Advantage of LED's

Jewelry is best shown under lighting provided from numerous point sources. This is critical especially for diamonds and other precious stones that are multi-faceted and reflect light from many different angles. The store owner mentioned the need for "pools of light".

The "pools" of light allow customers to easily see the – multi-dimensional nature of the luminaires as well as provide them a sharper appearance. Light is refracted from one facet to another within the stones through an effect known as return up-light. This effect gives diamonds and other precious stones their brilliance.

The store owner immediately recognized a key advantage of switching to LED's which have multiple point sources in one lamp is the increase in the number of angles at which a precious stone is illuminated. Illumination from multiple directions is an important design feature that retailers can use in lighting designs to improve the three dimensional nature to product display without needing to add additional luminaires.

ECONOMIC PERFORMANCE

Important: The cost and equipment assumptions made in this section apply only to Charles Koll. **Charles Koll assessed the replacement of incandescent light sources with LED light sources.** Readers of this document 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 LEDs. For LEDs luminaire/lamp lifetime is a function of all the manufacturer's 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. (*source:* http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds.pdf)

This section is based upon Charles Kolls's cost and savings estimates, as provided by the owner Malcolm Koll, to evaluate economic performance of the base case incandescent and the LED light source assessed in this project. Both a simple payback as well as payback considering maintenance cost of each was calculated.

1. Energy Cost Estimates

The energy cost is based upon the SDG&E® rate schedule as of July 2009. Under this rate schedule, the customer pays $0.14/kWh (rounded to two decimals). Charles Koll operates 4,368 hours annually. This project focused on the replacement of incandescent display case, accent and focal point lighting in the showroom area with LED lighting technology. Table 7 provides the energy cost and savings for the base case incandescent and the new LEDs installed at Charles Koll.

Table 7: Energy Cost Savings for Showroom

Light Source	Total Watts	Annual Energy (kWh)	Reduction (%)	Annual Energy Cost ($)	Annual Energy Savings ($)
Incandescent *	5,226	22,827	-	3,196	-
LED	1,748	7,635	67	1,069	2,127

* *Base case*

Note: The paybacks were calculated using the energy savings produced by the light source and did not take into consideration any energy reduction and associated savings due to the reduced heat load. The simple payback calculations for a retrofit scenario considered the total investment cost and energy savings for the LED. Tables 8 and 9 provide the simple paybacks for both a retrofit and new construction scenario. Table 10 reflects the retrofit payback when maintenance savings are considered.

Table 8: Simple Payback for Showroom – Retrofit

Light Source	Initial Investment ($)	Installation Cost ($)	Total Investment ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	-	-	-	3,196	-	-
LED	10,400	3,000	13,400	1,069	2,127	6.3

* *Base case*

Table 9: Simple Payback for Showroom - New Construction

Light Source	Initial Investment ($)	Incremental Cost ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Simple Payback (years)
Incandescent *	3,400	-	3,196	-	-
LED	10,400	7,000	1,069	2,127	3.3

* *Base case*

Table 10: Retrofit Payback for Showroom - Based Upon Energy & Maintenance Savings

Light Source	Initial Investment ($)	Installation Cost ($)	Total Investment ($)	Annual Maintenance Cost ($)	Annual Maintenance Savings ($)	Annual Energy Cost ($)	Annual Energy Cost Savings ($)	Total Annual Savings ($)	Simple Payback (years)
Incandescent *	-	-	-	1,200	-	3,196	-	-	-
LED	10,400	3,000	13,400	-	1,200	1,069	2,127	3,327	4.1

* *Base case*

Note: Installation cost assumed to be the same

2. Luminaires and Lamp Life

For LED technology, a properly designed fixture is required. The product must be well designed both electrically and thermally, in order to achieve its full 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, US DOE, 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.”

The manufacturers of the LED luminaires assessed in this project claim life expectancies of 35,000 hours (approximately 8 years at 4,368 operating hours per year).

3. Life Cycle Cost Analysis

To properly assess technology 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, etc. be determined for the specific project under evaluation. The results described in this project pertain to this specific application and situation at Charles Koll.

Due to the uncertainty as to future labor, product and other costs, especially for LED technology, readers are recommended to use their judgment regarding the future costs. In the case of this project pricing for portions, specifically the display case phase, reflected earlier generation LED pricing. Therefore, the economic analysis may not reflect current LED pricing.

Future Projects

This project illustrates a very important opportunity for future projects and studies for the ETP. Studies of the behavioral influences on market adoption of emerging or new technologies such as LED's in the retail industry would be important to the adoption of high energy efficiency lighting measures. LED technology's ability to meet the visual merchandising needs of retailers without compromising the shopping experience of their customers is crucial at this juncture.

To fuel the adoption of high efficiency light sources such as LED's in the retail market will require:

- understanding of the "true" market needs for lighting in visual merchandising from the retail manager, design team and shoppers perspectives and understand specifier needs for such attributes as color quality
- education and communication retailers feedback on the quality of light in different applications within a store (not just a design or standards vantage point) to lighting designers and manufacturers
- further studies of the interplay between different lighting systems within a retail space such as ambient lighting, task lighting, focal-point lighting, display case lighting, accent lighting, perimeter and support space lighting.

Conclusion

This assessment project demonstrated that a complete LED retail showroom retrofit can be accomplished. Significant energy savings (67% overall), improvement in customer comfort, enhanced lighting and consistency of product appearance, were possible while maintaining proper light intensity, CCT and CRI throughout the showroom area.

The store owner was adamant and restated many times throughout the project that energy efficiency was not a sufficient reason to change over to new lighting technologies for the focal point and accent lighting applications, no matter how deep the savings. He expressed that one lost sale by a jeweler due to inadequate lighting could possibly eliminate an entire year's energy cost savings plus the loss of a customer loyalty.

The lessons learned from this assessment are as follows:

- a complete replacement of focal point and display case lighting is possible and acceptable in a retail environment
- the light qualities required by the retail market segment, regardless of the technology, must take into account the visual merchandising needs of the individual stores and address the following key metrics:
    - *Light intensity*
    - *Color rendering or "Honest Light" as described by the store owner*
    - *Attractive and unobtrusive light fixtures*
    - *CCT*
    - *Interplay between different lighting systems is crucially important to achieve energy savings and meet the need to create the right "atmosphere" and elicit "good feelings" from the consumer*
- adequate in situ testing must be completed before adopting new technologies
- cautious reliance on marketing brochures and technical data sheets
- just because LED lighting does not achieve the same measured output as traditional lighting, does not mean it is not appropriate. LED lamps have tremendous potential when utilizing their directional nature to illuminate specific areas.

In summary, retail lighting designers use color qualities of light, intensity, fixture design in traditional retail lighting design. Opportunities exist for the design industry to use the multiple- point source advantages of LED lamps as an innovative design tool as was demonstrated in this assessment.

An important statement was made by the owner, “With the new emerging technologies, the biggest barrier may be adapting to a new type of lighting and associated standards. He went on to state, “Just because LED lighting does not achieve the same measured output as traditional lighting, does not mean it is not appropriate. It all comes down to behavioral adaptation since we are all creatures of habit.”

The results of this assessment indicate a longer payback period than most retailers accept. However, as LEDs gain acceptance and continue advancing, expectations are that linear LED display case luminaires and direct replacement PAR lamps will see a reduction in price the near future. Utility incentives could also help in the short-term to make LEDs more cost-effective for customers fueling earlier adoption of the new technologies.

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 lighting 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 for Display Cases

Pre and Post LED Installation Data for Display Cases

Case Lights only				
	Pre-LED		Post-LED	
Data Point	Illuminance (fc)	CCT (K)	Illuminance (fc)	CCT (K)
a	17	2,785	99	3,688
b	23	2,701	116	3,599
c	20	2,680	104	3,576
d	69	2,735	340	3,648
e	66	2,626	356	3,597
f	67	2,646	345	3,592

Temperature (°C)				
	Pre-LED		Post-LED	
Position	Outside (glass)	Inside (air)	Outside (glass)	Inside (air)
back	23	25	21	25
center	24	27	23	26
customer	33	38	26	32

Appendix B

Data for Focal Point Lighting

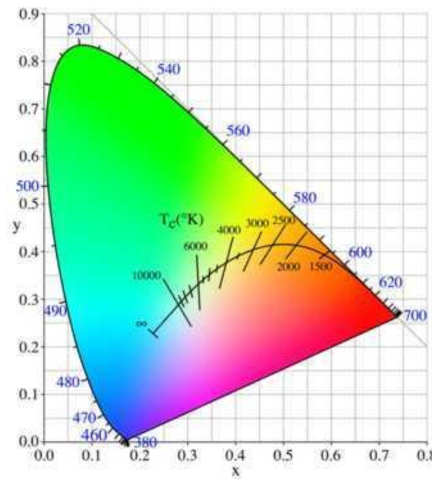
Pre and Post LED Installation Data for Focal Point Lighting

	Pre-LED				Post-LED			
	Case 1		Case 2		Case 1		Case 2	
Data Point	Illuminance (fc)	CCT (K)	Illuminance (fc)	CCT (K)	Illuminance (fc)	CCT (K)	Illuminance (fc)	CCT (K)
a	87	3,585	86	3,325	119	3,952	126	4,051
b	67	3,589	100	3,390	121	4000	116	3,978
c	88	3,635	90	3,520	118	4000	99	3,930
d	108	3,660	106	3,475	126	4000	109	3,940
e	90	3,600	61	3,690	118	4000	128	4000
f	88	3,600	56	3,695	111	3,992	122	4,010
Average	88	3,608	83	3,516	119	3,991	117	3,985

Appendix C

Lighting Characteristic Discussion

Color Temperature



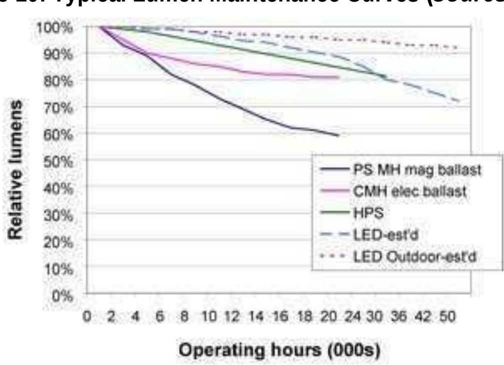
Temperature, or Chromaticity, is a measure in degrees Kelvin that indicates the appearance of a source. If a steel rod were placed into a fire it would first turn red, then orange as it heats up, until it finally turns bluish white. The temperatures of the rod and the color at each temperature describe the color of a source. It may sound like a contradiction, but low color temperature lamps have more red wavelengths, thus creating a warm feeling. High color temperature lamps have more blue wavelengths creating a cool feeling.

The figure to the right shows displays the International Commission on Illumination (CIE) chromaticity space, as well as the chromaticity of black-body light sources of various temperatures and lines of constant correlated color temperature. As the Kelvin Temperature increases from right to left into the chromaticity space, the color temperature changes from red to blue. Monochromatic wavelengths are shown in blue in units of nanometers around the outside of the space.

Lumen Maintenance

LED and induction lumen depreciation is minimal compared to conventional lighting sources. The provided charts below give typical lumen maintenance curves for various light sources corresponding to their estimates of lumen maintenance for burn hours. It should be noted however, that since the expected average annual nighttime temperature is below 25°C, and no comparable luminaire has been operated for over 100,000 hours (nearly 25 years at 4,100 hours per year), no independent data is available to corroborate this figure.

Figure 10: Typical Lumen Maintenance Curves (*Sources: www.eere.energy.gov & www.miserlighting.com*)



Estimating LED and induction lamp life is problematic because the long projected lifetimes make full life testing impractical, and because the technology continues to evolve quickly, superseding past test results. Most manufacturers define useful life based on the estimated time at which light output will depreciate to 70% of its initial rating; often the target is 50,000 hours for interior luminaires, but some outdoor luminaires are designed for much longer useful lives of 100,000 to 150,000 hours. Luminaire manufacturers typically determine the maximum drive current and junction temperature at which the fixtures will produce greater than 70% of initial lumens for at least the target useful life in hours. If the lamps are driven at lower current and/or maintained at lower temperatures, useful life may be greatly increased.

In general, LEDs and induction lighting in well-designed luminaires are less likely to fail catastrophically than to depreciate slowly over time, so it may be difficult for a utility or maintenance crew to identify when to replace the luminaire. In contrast, poorly designed luminaires may experience rapid lumen depreciation or outright failure.

Thermal management is critical to the long-term performance of the LED, since heat can degrade or destroy the longevity and light output of the LED. The temperature at the junction of the diode determines performance, so heat sinking and air flow must be designed to maintain an acceptable range of operating temperature for both the LEDs and the electronic power supply. For induction lighting, the temperature sensitivity of the generator, which is a solid-state electronic device that can fail prematurely if it gets too hot, is also critical to long-term life. While HID systems can operate at temperatures of 90°C -105°C, induction systems are limited to the 70°C-75°C range. The luminaire manufacturer should provide operating temperature data at a verifiable temperature measurement point on the luminaire, and data explaining how that temperature relates to expected light output and lumen maintenance for the specific technology used.

All light sources experience a decrease in light output (lumen depreciation) over their operating life. To account for this, lighting designers use mean lumens, usually defined as luminous flux at 40% of rated life, instead of initial lumens. For LPS lamps, mean lumens are about 90% of initial lumens. Pulse-start MH mean lumens are about 75% of initial lumens, while ceramic MH lamps have slightly higher mean lumens, around 80% of initial lumens.