# A Scaled Field Placement of Advanced Track LED Fixtures in a Grocery Environment

*ET Project Number: ET 12PGE3351*

**Project Sponsor:** Carolyn Weiner, PG&E
Pacific Gas and Electric Company

**Prepared By:** Teddy Kisch, LC, Project Manager II
Jeff Steuben, Project Manager
Terrance Pang, Director

Energy Solutions
1610 Harrison St
Oakland, CA 94612

**Issued:** December 28, 2012



Pacific Gas and Electric Company®

## ACKNOWLEDGEMENTS

Pacific Gas and Electric Company's Emerging Technologies Program is responsible for this project. It was developed as part of Pacific Gas and Electric Company's Emerging Technology – scaled field placement program under internal project number ET12PGE3351. Energy Solutions conducted this technology evaluation for Pacific Gas and Electric Company with overall guidance and management from Carolyn Weiner. For more information on this project, contact C1WA@pge.com.

The authors would like to gratefully acknowledge the direction and assistance of Pacific Gas and Electric Company and Safeway, Inc. for their participation and support of this project.

## LEGAL NOTICE

This report was prepared for Pacific Gas and Electric Company for use by its employees and agents. Neither Pacific Gas and Electric Company nor any of its employees and agents:

(1) makes any written or oral warranty, expressed or implied, including, but not limited to those concerning merchantability or fitness for a particular purpose;

(2) assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, process, method, or policy contained herein; or

(3) represents that its use would not infringe any privately owned rights, including, but not limited to, patents, trademarks, or copyrights.

# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| B50 | Rated life of a halogen lamp |
| CBCP | Center beam candle power |
| CALiPER | Commercially Available LED Product Evaluation and Reporting Program |
| CCT | Correlated color temperature |
| CD | Candela, unit of lighting intensity |
| CRI | Color rendering index |
| DLC | DesignLights Consortium |
| DOE | US Department of Energy |
| IES | Illuminating Engineering Society |
| IR | Infrared |
| L70 | Rated life of an LED product |
| LED | Light emitting diode |
| LM-79 | Method for Electrical and Photometric Testing of Solid-State Lighting Devices |
| LM-80 | Method for Measuring Lumen Depreciation of LED Light Sources |
| LPW | Lumens of light output per watt of electric input, the unit of lighting efficacy |
| MR | Multifaceted reflector |
| PAR | Parabolic aluminized reflector |
| PF | Power factor |
| ROI | Return on investment |
| THD | Total harmonic distortion |
| TM-21 | Method for Projecting Long Term Lumen Maintenance of LED Light Sources |

# FIGURES



# Tables

# CONTENTS

# EXECUTIVE SUMMARY

The project goal was to evaluate the performance of the 15W Amerlux Hornet LED fixture as a potential replacement for a variety of low voltage halogen MR16 track lighting applications in a Northern California Safeway grocery store.

Given their small form factor and design, which enables them to provide a controlled spot-light effect, MR16 lamps are widely used for accent, task and display lighting in retail and gallery spaces. There are roughly 122 million MR16 lamps installed in the US, and over 98% of these are halogen lamps. These MR16 lamps consume 11,200 Gigawatt hours (GWh) per year in the US (Navigant 2011) and an estimated 544 GWh per year within Pacific Gas and Electric Company (PG&E) territory. While LED lighting has the potential to achieve significant energy savings in MR16 and other directional lighting applications, high quality LED replacement lamps and integrated LED fixtures for 35W and 50W MR16s have only recently become available (DOE 2012).

The study replaced 62 50W halogen MR16 lamps and fixtures with 45 15W Amerlux Hornet integrated LED fixtures and evaluated them based on power and energy usage measurements, lighting performance characteristics, qualitative satisfaction, and economic factors. In addition, the project sought to understand the customer's internal product selection processes and their decision to install this Hornet fixture across multiple locations.

Overall, Safeway was very satisfied with the energy savings, projected maintenance savings, and lighting quality provided by the Hornet fixture. On a per fixture basis, the Hornet fixture achieved 69% savings in electric power demand and energy use, with estimated energy savings of 278 kWh per fixture per year. The Hornet replacement was used as a comprehensive lighting solution that allowed for a reduction in total fixtures rather than a one to one fixture replacement, allowing for greater energy and maintenance savings. Including fixture reductions, on a store level the Hornet fixture achieved 77% savings in demand and energy use and 35% projected maintenance savings due to LED longevity and elimination of halogen relamping needs. This project achieved an estimated 3.6 year payback based on electric energy savings alone, and a 2.8 year payback when including maintenance savings. However, this longer payback period accounts for installation costs, which increase the total retrofit costs by 60%. Payback periods can be significantly reduced by incorporating installation into scheduled maintenance. Overall, the project resulted in a total savings of $19,793 over the estimated 5.7 year lifetime of the LED, or a 105% ROI for that same period.

The Hornet fixture improved lighting quality over the base case in multiple applications by decreasing contrast levels and reducing the prevalence of hotspots and underlit areas, which was primarily due to a change in beam angle. While the 15W fixture provides a high level of overall lumen output comparable to a 50W MR16, its center beam candle power (CBCP) levels slightly lower than a 50W MR16 fixture when using an equivalent beam angle, particularly for beam angles below 35°. For applications which require CBCP levels equivalent to a 50W halogen MR16, we recommend using the 21W Hornet fixture. In addition, the integrated fixture design was also helpful in that it mitigated any potential issues of compatibility with line and low voltage tracks and transformers.

Using its interchangeable lenses to achieve different beam angles, the 15W Hornet fixture also demonstrated a high level of controllability.[1] This feature is especially well suited for spaces with frequently changing lighting requirements such as retail or gallery applications. This feature represents a significant improvement in lighting control over existing halogen MR16 lamps and LED replacement lamps and could dramatically reduce maintenance and material costs for applications where spaces are relamped simply to achieve different lighting effects.

The fixture evaluated, and similar performing products, provides significant energy and maintenance benefits while offering a high level of controllability typically desired in retail, hospitality, and grocery sectors.

We recommend that PG&E integrate this fixture and any other similar fixtures into future commercial advanced LED programs. In addition to achieving energy savings of over 70%, the retrofit achieved a 103% reduction in peak demand when including interactive factors. This fixture has the potential to dramatically reduce utility peak demand because of the high demand interactive factors associated with retail and grocery applications. Furthermore, its dimming capabilities allow for integration with future utility Auto Demand Programs to provide additional peak demand savings.

The Hornet fixture is one of the first suitable 50W MR16 replacements, and there still remain a number of market barriers which utility programs can help to address. While Safeway has a highly refined product selection process and a high degree of internal lighting expertise, there are many companies that lack the internal expertise that could significantly benefit from utility programs which provide detailed product information and established qualification criteria. This effort would significantly reduce information and search costs for companies evaluating replacement options for halogen track lighting. While energy and maintenance savings are the primary drivers of energy efficiency decisions, incentives continue to play an important role in increasing market adoption of LED fixtures and encouraging companies to make energy efficient decisions. Of the150 stores which Safeway plans to retrofit from halogen MR16 fixtures to integrated LED fixtures in 2013, 100% of them are in a utility territory which has an existing commercial advanced LED incentive program. This strongly suggests the importance of a commercial LED incentive program in addressing barriers to the widespread market adoption of high quality LED fixtures in track lighting applications.

We recommend that PG&E conduct a follow-up Phase II study in late 2013 once Safeway has installed the Amerlux fixture across 150 installations in California. This study would focus on the longer-term product performance, lessons learned in the process of scaling up, comparisons of the base and retrofit cases using similar beam angles, and additional retrofit opportunities for the Hornet fixture, including wall-wash and recessed applications.

[1] This is a relatively new product feature, and there are very few existing integrated fixtures or LED replacement lamps which have this capability at this time. A recent DOE GATEWAY study in Washington, D.C, tested an OptiLED replacement lamp which used interchangeable lenses to achieve different beam angles (DOE 2012d).

# INTRODUCTION

MR16s are small diameter directional lamps commonly found in retail, museum, gallery, and entertainment applications. Given their small form factor, narrow beam angles and highly directional, focused light, they are widely used for accent, task and display lighting. MR16 lamps dominate the small diameter directional lamp market, with over 122 million MR16 lamps installed in the US, 78 million of them in commercial applications (Navigant 2011), primarily in the retail and hospitality sectors. Of this installed base, over 98% are halogen MR16s, while LED lamps and fixtures constitute less than 2% of the market. MR16 lamps consume an estimated 11,200 Gigawatt hours (GWh) of electricity per year nationally (Navigant 2011) and 544 GWh per year within PG&E territory.[2]

In grocery applications, MR16 lamps are typically track mounted and illuminate signs, shelving, or particular products of interest. The low efficacy (light output per electric power input, typically 5-25 lumens per watt) and short lifetime (2,000-10,000 hours) of halogen MR16s make LEDs a good replacement candidate, whose long lifetime could offer substantial energy and maintenance savings (Energy Solutions 2012). This is particularly true for grocery and other retail applications, where long operating hours lead to frequent burnouts and replacement of halogen lamps.

As efficacy and total lumen output of LEDs continues to improve, there has been growing interest in replacing halogen MR16s with LEDs. LED replacements for MR16s come in two forms, either as a complete fixture consisting of a lamp and integrated driver, or as simply a replacement lamp that can be housed within the existing fixture. Both lamp replacements and integrated fixtures have inherent advantages and disadvantages.

LED MR16 replacement lamps often provide a more affordable retrofit option than an integrated fixture, as they eliminate the cost of replacing existing fixtures and transformers. However, LED replacement lamps are not universally compatible with existing fixtures (particularly existing transformers and dimming systems), and compatibility must be determined prior to the retrofit (LEDs Magazine 2012).[3] Replacing the entire fixture with an integrated LED fixture is recommended to eliminate transformer compatibility issues and improve thermal management of LEDs.

In 2008, the Department of Energy (DOE) Commercially Available LED Product Evaluation and Reporting (CALiPER) program released a report benchmarking the performance of halogen MR16 replacement lamps and their commercially available LED replacements. This report found that a number of products had low color rendering index (CRI), unreliable correlated color temperature (CCT), low total lumen output, poor power factor (PF), and often did not live up to manufacturer claims found in the product literature (DOE 2008). Recent field testing of replacement lamps in a San Francisco, CA hotel under DOE's

---

[2] MR16 energy use within PG&E territory estimated based on service territory population size compared to national population using 2010 US Census data table NST-EST2011-01. http://www.census.gov/popest/data/state/totals/2011/index.html.

[3] A recent DOE GATEWAY demonstration of MR16 replacement lamps at the Smithsonian Museum in Washington, D.C. found that compatibility with existing transformers and dimming systems was a major barrier to replacing existing halogen MR16 lamps (DOE 2012d).

GATEWAY program found similar issues with low total lumen output and long-term reliability (DOE 2012c). At present, most LED MR16 replacement lamps are only suitable for replacement of 20W and 35W halogen MR16s and there are few or no replacements for a 50W halogen MR16 (LEDs Magazine 2012b, DOE 2012a).

Integrated LED fixtures do not have the transformer compatibility problems and have fewer thermal management issues than replacement lamps, and are generally considered to be more 'market ready' for 50W halogen MR16 fixtures. However, a disadvantage of integrated fixtures is that they require existing fixtures and transformers to be removed, and are more expensive on a per fixture basis than integrated lamps. The additional installation requirements and higher initial cost of integrated fixtures is a potential barrier to widespread adoption of integrated fixtures.

Safeway, Inc. is a major North American grocery store chain based in Pleasanton, CA with 1,678 grocery stores across the US and Canada. Safeway's primary goals for retrofitting existing track lighting were to improve lighting quality while simultaneously achieving significant energy and maintenance savings. After conducting a detailed, multi-year fixture selection process, Safeway tested the Amerlux Hornet fixture with the explicit goal of achieving energy savings of 30%, maintenance savings of 50%, fixture reductions of 20%, and also improving overall lighting quality by eliminating hotspots and underlit areas produced by the existing halogen MR16 lamps.[4]

In 2012, in collaboration with PG&E's Emerging Technologies program and the LED Accelerator (LEDA) program,[5] Safeway Inc. began assessing the performance of the Amerlux Hornet LED fixture in replacing 50W halogen MR16 lamps and fixtures in two Northern California Safeway stores.

Safeway began a partial MR16 retrofit one of these two stores just prior to the commencement of this study, and consequently this site did not have baseline data. Therefore, the focus and scope of this study was limited to one store in order to provide a complete set of base case and retrofit measurements. While the second site was not included in the technical measurements, Safeway's installation experience and product satisfaction is included in the discussion of Safeway's fixture selection and decision making survey.

# BACKGROUND

Small diameter directional lamps have a diameter of two inches or less and are used to provide focused lighting for accenting, task or display purposes. The most common lamp is the Multi-faceted Reflector-16 (MR16), where the number designation following the lamp acronym refers to the diameter of the lamp in 8[ths] of an inch; i.e., an MR16 is two inches

[4] As part of this change from halogen to LED fixtures, Safeway increased the fixture beam angle to a wider, linear spread. MR16 fixtures are designed to provide crisply defined beam angles, and the presence of hotspots and underlit areas should not be considered an inherent flaw of the base case fixture itself. Rather, Safeway's desire to reduce hotspots and underlit areas suggests a broader beam angle is best suited for this application.

[5] PG&E's third party LEDA program, administered by Energy Solutions, provides large multi-site commercial businesses with calculated incentives for installing cutting edge LED products in large numbers. The program also offers customized technical support, including lighting audits, product demonstration and selection, and product specification assistance. For more information, see http://ledaccelerator.com/

(16/8) in diameter. Parabolic Aluminized Reflector-16s and -11s (PAR16, PAR11) and MR11 comprise a smaller subset of the small diameter directional lamp category. This type of lighting is intended to complement general area lighting such as that provided by linear fluorescent or metal-halide high-bay fixtures, but not to replace them entirely. Lighting designers typically use these lamps in retail and gallery environments to highlight or draw attention to specific areas using a combination of dimming, lenses and aiming adjustments.

**FIGURE 1 – HALOGEN MR16 LAMP**

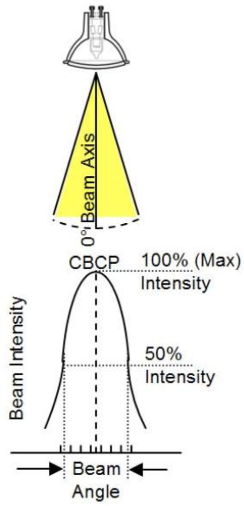
**Halogen MR16**

A halogen MR16 lamp operates in a similar fashion to traditional incandescent lamps, with some minor differences. Electricity passes through a filament, which incandesces and produces light. The filament is contained within a sealed quartz capsule filled with a halogen gas nested in a reflector which focuses the light beam. Tungsten particles evaporating off the filament react with the halogen gas which redeposits the tungsten onto the filament, prolonging lamp life and maintaining lumen output over time (RPI 2002). The specific beam angle can be modified through adjusting the geometry of the reflector and capsule. Like incandescent lamps, halogen lamps convert 90% of their energy into heat, which creates large amounts of heat as a by-product of lamp operation (DOE 2008).

Halogen MR16 fixtures and lamps are often mounted on tracks and within housings that hold the fixtures in place and deliver voltage and current to the fixtures. MR lamps are unique in that roughly only 10 percent operate on line voltage (e.g. 120V) while the remaining large majority operate on low voltage (e.g. 20V). PAR lamps typically operate on line voltage. Operating at low voltage causes the current passing through the filament to be roughly ten times higher than regular incandescent lamps operating at 120V. MR16s and MR11s operating on low voltage can use thicker, more robust filaments that allow the lamps to burn brighter and create a crisper beam angle within which light is concentrated. Voltage may be transformed to low voltage by a central magnetic transformer before being delivered to the track mounts ("low voltage tracks") or may be carried at full line voltage by the track and transformed by smaller individual electronic transformers integrated into each MR16 fixture on the track ("line voltage tracks"). Magnetic transformers come in two types: *laminated stack*, which are 80-85% efficient, and *toroidal*, which are 90-95% efficient (Arcadian Lighting 2012). Both magnetic transformer types last between 15-25 years, and constitute the majority of the installed base of transformers. Electronic transformers constitute the majority of new shipments, and have the advantage of being small and cheap, and can also be installed adjacent to the fixture. However, the electronics are sensitive to high temperatures and tend to last five years or less (Arcadian Lighting 2012).

Due to the directional nature of MR16 lamps, lighting performance of MR16s is typically evaluated by Center Beam Candle Power (CBCP), which is the luminous intensity at the center of that beam for a specified beam angle, measured in candelas (RPI 2002), in lieu of total lumen output. The width of the beam angle is calculated as the angle where the light source beam intensity is 50% of the maximum intensity (typically from the center of the lamp in a directional source like an MR16), depicted in Figure 2. A narrower beam will have a higher CBCP as the light output is focused over a smaller area.

**FIGURE 2 – BEAM ANGLE AND CENTER BEAM CANDLE POWER**




Source: DOE 2008

Efficacy is a measure of how efficient a light source is at converting electrical energy into light output, measured in lumens per watt (LPW). Typical halogen efficacy ranges from 5-25 LPW, depending on the particular lamp and fixture components.

Correlated Color Temperature (CCT) is a scale that characterizes the dominant color of the light output, ranging from warm yellow or red colors to cool blue colors *(*RPI 2002*)*. The Color Rendering Index (CRI) describes the color quality of light and its ability to accurately render a variety of colors, as defined by the International Commission on Illuminination (CIE). The index has a maximum value of a 100, and light sources below 50 are generally regarded to have poor color rendering ability (RPI 2002).

Halogens typically have a CRI of 100 and have a color temperature of 3000K, slightly higher than a typical 2700K "warm" incandescent lamp (DOE 2008). Halogen fixtures operating at lower than designed voltages, whether through dimming capability or voltage drop present in the installation, will produce a lower color temperature due to decreased filament temperature (Fiberoptics Technology 2012).

The rated lifetime of halogen lamps is the amount of time it takes for 50% of the test lamps to fail (B50). This number, therefore represents the median life of a lamp, and some lamps will last much longer than the rated life while others will fail prematurely before that time.

Halogen MR16 lamps have a rated lamp life ranging from 2,000 to 10,000 hours (RPI 2002). The range in lamp life is attributed to differences in lamp and filament design. Halogen lamp manufacturers utilize inert fill gas, infrared (IR) coatings, filament capsule geometry, and reflector design to increase the lamp life (ECEEE 2011). IR halogens have a coating that selectively reflects infrared radiation, increasing filament temperature and producing more light for the same amount of energy.

Table 1 highlights typical efficacies and product lifetimes for different halogen MR16 and LED replacement fixtures.

**TABLE 1 – HALOGEN AND LED MR16 COMPARISON**

| Design Option | Halogen - non IR | Halogen w/ infrared coating | Improved reflector coatings, IR coatings, or capsule designs | LEDs – Gen. 1 | LEDs - newer chip & electronic configs. |
|---|---|---|---|---|---|
| **Efficacy (LPW)** | 5 - 13 | 10 - 19 | 18 - 25 | 35 - 45 | 45 - 70 |
| **% Reduction in Energy Consumption from Baseline** | 0% | 23% | 42% | 75% | 83% |
| **Average Lifetime Hours per Lamp** | 2,000 - 3,000 | 3,000 - 6,000 | 3,000 – 10,000 | ~25,000 | > 35,000 |
| **Current Market Share** | 80% | 16% | 3% | 1% | < 1% |

Source: Energy Solutions 2012

**Project Application**

Safeway's existing track lighting uses MR16 fixtures with Sylvania 50MR16/B/FL35 12V lamps. This 50 watt lamp is configured with a 35 degree beam angle ("designated "Flood"), and a CBCP of 2200 candela. Within Safeway, the MR16 lamps are used in several different applications. In the wine (low voltage tracks) and seasonal decoration sections (line voltage tracks), the lamps illuminate price tags and product labels. In the deli department (low voltage tracks), the lamps illuminate product display and ordering signs. Color rendering, color temperature, and lighting distribution are important for each of these applications. The existing fixtures have a nominal color temperature of 3000K and CRI of 100 (Osram Sylvania 2012).

# EMERGING TECHNOLOGY/PRODUCT

The Amerlux Hornet, pictured in Figure 3 is a 15W LED fixture designed to replace 50W halogen MR16 lamps. The Hornet also comes in 12W and 21W configurations (with lower and higher lumen output, respectively), and can be installed as track lighting or a recessed fixture.[6]

[6] For more information on the Hornet fixture, see http://www.amerlux.com/products?f=82

## FIGURE 3 – AMERLUX HORNET FIXTURE

Source: Amerlux 2012

Due to the differences in how traditional halogen and LED technologies produce light, the fixtures cannot be evaluated using the same test methods. The standard test method for solid state lighting fixture performance is the Illuminating Engineering Society's (IES) LM-79, *Electrical and Photometric Testing of Solid-State Lighting Devices.* Reports from LM-79 testing provide useful performance characteristics to allow for comparison of LED products and models amongst each other as shown in Table 2, and against other lighting technologies.

The testing method for determining depreciation of LED chip or array output is LM-80, *Measuring Lumen Depreciation of LED Light Sources*. A methodology has also been developed to use chip-level lumen depreciation results (from LM-80) and chip operating characteristics in a given light source (such as operating temperature) to estimate LED product lifetimes. This is known as TM-21, *Projecting Long Term Lumen Maintenance of LED Light Sources*.

Likewise, calculating the useful life of LED products differs from traditional technology. For halogen bulbs, the rated life of the product is the B50 lifetime as described previously. The rated life for LEDs, which slowly dim over time rather than fail entirely, is known as L70, the time at which the lumen output reaches 70% of its original value. Because of the extremely long product life of LEDs (e.g. 50,000 hours or more), the LM-80 test procedure collects lumen depreciation data over 6,000 hours, and this data is used to extrapolate the expected product life using TM-21 methods.

## TABLE 2 – HORNET LM-79 TEST DATA

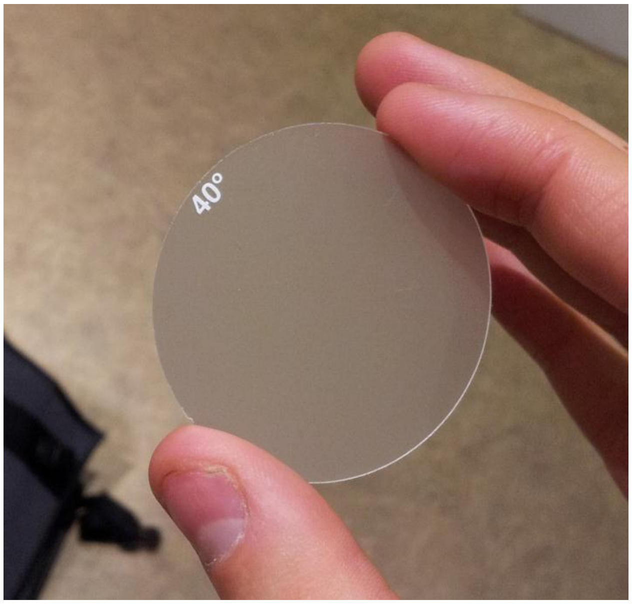
| | Spot (15°) | Flood (28°) | Wide Flood (45°) |
|---|---|---|---|
| CBCP (candela) | 6183 | 2478 | 1160 |
| Total Lumens (lm) | 864.3 | 819.9 | 822.0 |
| Efficacy (LPW) | 55.9 | 53.1 | 53.2 |
| Current (Amps) | 0.13 | 0.13 | 0.13 |
| Power (W) | 15.5 | 15.5 | 15.5 |
| PF | 0.99 | 0.99 | 0.99 |

Source: UL 2012

The Amerlux Hornet fixture has three core components - the solid state light source, an electronic LED driver, and an interchangeable optical lens. The driver serves a similar role to the transformer in the halogen product and converts incoming line voltage to low voltage; it also rectifies the alternating current provided by the utility to direct current, and protects the LED from line voltage fluctuations. This configuration is comparable in size to halogen MR16s with built-in electronic transformers, but is physically larger than MR16 fixtures which use a remotely placed transformer for an entire track of lamps.

The Hornet's interchangeable optical lens, shown in Figure 4, can be used to achieve different beam spreads ranging from a narrow 15° beam to a wide 60° x 10° "linear spread". These adjustments can be made simply by unscrewing the fixture cover and installing a different lens, and can be completed in roughly 1-2 minutes. The beam angle is a product of the optics from the focused beam combined with an optical lens. For example, the 40° lens depicted in Figure 4 combines with the SSL source to produce a 45° beam angle. In addition, custom beam spreads can be developed for long displays, wall washing, spots and floods. This product feature may be highly desirable in track lighting MR16 applications such as retail and gallery lighting, where lighting needs can continuously shift with display changes. The use of interchangeable optical lenses also suggests that a single fixture type could be used for a wide variety of applications, from wall washes to spot lighting.

**FIGURE 4 – HORNET BEAM ANGLE ADJUSTMENT LENS**




Source: Author

Similar to the range of available beam angle configurations, the available color temperatures of the fixture range from 2700K to 4000K.

Nominal lumen output for the 15W Hornet fixture ranges from 810 lm to 830 lm, depending on the beam angle selected which yields an efficacy of 53-56 LPW. The product has a rated life of 50,000 hours (L70). The product specification sheet does not list the fixture's CBCP, but test results obtained from Underwriters Laboratories (UL) indicate a range from about 1160 to 6180 depending on the selected beam angle configuration, as shown in Table 2.

**Product Comparison**

According to product specification sheets, the Amerlux Hornet fixture uses roughly 30% of the power and has a rated lifetime 12.5 times longer than the installed halogen fixture. Table 3 compares key product characteristics using data from product specification sheets. The CBCP for the 60° beam angle was not available, so the value was estimated based on the performance of the Spot, Flood, and Wide Flood beam angles of the same fixture. This method for estimating CBCP is described in further detail below.

**TABLE 3 – HALOGEN AND LED PRODUCT COMPARISON**

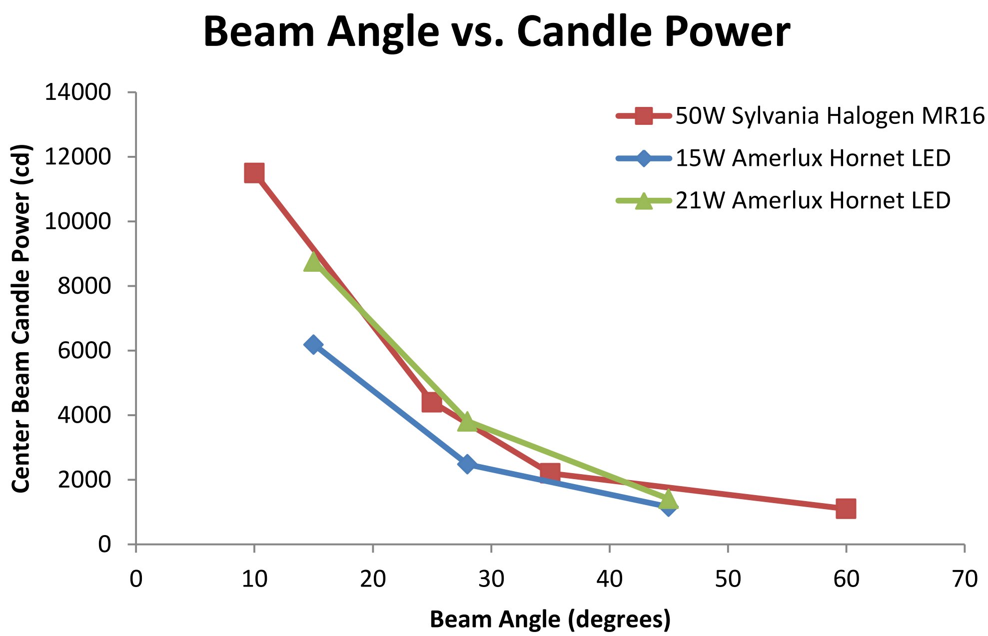
| | Halogen | LED |
|---|---|---|
| Power (W) | 50 | 15 |
| Rated Life (hrs) | 4,000 | 50,000 |
| Beam Angle (°) | 35° | 60° |
| CBCP (candela) | 2200 | ~500 [7] |
| CCT (K) | 3000 | 3000 |
| CRI | 100 | 85 |

Sources: Sylvania 2012, Amerlux 2012

Light output for directional lighting products such as MR16s is commonly evaluated by lighting intensity, or CBCP, rather than total light output (lumens). The intensity of the light fixture is dependent on beam angle, as a tightly focused beam results in more concentrated light over a smaller area. As noted previously, the choice by Safeway to move to a wider beam angle from the base case to the retrofit results in very different CBCP values. A direct comparison of the two technologies is difficult they are not available in the same beam angle configurations. However, using data from LM-79 test reports for three different beam angles of the Hornet fixture and Sylvania product specification sheets, a relationship between the fixtures' CBCP and beam angle can be determined, as shown in Figure 5. The estimated CBCP value of the Hornet fixture with a 60-degree Linear Spread configuration was calculated using a regression equation that fit the three data points shown. The curve for the 15W Amerlux fixtures is shifted to the left of the halogen fixtures, which means it does not have the same level of lighting intensity provided by the 50W halogen product at a given beam angle configuration. This difference is much greater for beam angles under 35° and is much smaller for beam angles over 35°. However, the CBCP levels for 21W Hornet fixture are closely aligned with a 50W halogen, which suggests that the 21W fixture should be used in applications which require high CBCP levels similar to a halogen MR16. In applications that do not require the high CBCP levels of the 50W halogen fixture, the 15W fixture should provide sufficient lumen output. It should be noted that although the 15W fixture has lower CBCP levels than the halogen fixture, Safeway was very satisfied with the fixture's performance and overall lumen output.

[7] The CBCP value for the 60° beam angle was not available and therefore estimated based on a regression analysis of the other beam angle configurations of the 15W Hornet fixture. The regression is $y=13185e^{-.055x}$ and has an $R^2$ value of 0.983.

**FIGURE 5 – COMPARISON OF BEAM ANGLE AND CANDLE POWER OF HALOGEN AND LED FIXTURES**




Another area where the LED product does not meet or exceed the product specifications of the halogen lamp is its color rendering index. Halogens have the maximum possible CRI of 100, whereas the Hornet fixture has a CRI of 85, with a possible optional configuration of 90 CRI. The impact of this decrease in CRI is a slight reduction in the accuracy of the way colors are represented when illuminated by the light source. However, a CRI of 85 is generally regarded as providing good color rendering. For reference, the minimum CRI requirement for LED directional fixtures for both DLC and Energy Star qualification is 80.[8]

The long lifetime of LED fixtures provides a significant maintenance benefit. The Hornet's has a rated lifetime of 50,000 hours, roughly 12.5 times longer than a halogen MR16, and like similar LED products comes with a warranty. This long lifetime dramatically reduces maintenance costs, and is especially useful in retail, grocery, and museum applications due to the high maintenance costs of relamping fixtures. The Hornet's use different optical lenses to achieve a variety of beam angles may also reduce maintenance costs, since a halogen requires relamping to achieve this same effect. Maintenance savings for this store are discussed in detail in the 'Energy Savings and Economic Impact' section.

Another advantage of the LED fixture is a decrease in sensible heat emitted from the light beam. LED products emit less heat overall due to higher conversion efficiency (of electric power to light), and the heat generated is concentrated on the LED chip, which is diffused into the environment through heat sinks and fins. This diffuse heat contrasts to a halogen lamp which emits a large portion of the heat with the light beam, concentrating it on the

---

[8] For complete DLC product requirements, see: http://www.designlights.org/solidstate.manufacturer.requirements.php.
For complete Energy Star requirements for Integrated Fixtures, see: http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf

illuminated area. This is of particular interest for food, clothing, or art applications, temperature sensitive products illuminated by the fixtures can be warmed by the halogen lamps and result in decreased product life or quality. Additionally, halogen fixtures without sufficient clearance from ceiling tiles, walls, or other objects, can pose a fire hazard.

### Interactive factors

An important consideration for electric lighting and other electricity and natural gas end uses inside the built environment is the way these loads interact with one another in summing to the total energy demands of a building. The relationships between an electric energy end use and the HVAC load of a building are often referred to by utilities as HVAC 'Interactive Factors'. The Interactive Factor of lighting energy and other end uses on HVAC loads is largely dependent on the energy end use, building type, building vintage, and climate zone.

More efficient, lower wattage light sources emit less heat into a conditioned space. Most retail environments in California have more HVAC cooling load than heating, and therefore the reduction in heat output from a more efficient lighting fixture generates additional electric energy and demand savings. In large grocery stores however, the presence of reach-in refrigerator and freezer cases help cool the air within a grocery store somewhat, so additional heating from the HVAC system (both electric and gas demands) is often required during the morning and evening to maintain a comfortable ambient temperature. Heat from light sources can help to meet this heating load. On the other hand, warm afternoons coinciding with the peak demand period for electric utilities require additional HVAC cooling energy so any reductions in heating within the space (including from light fixtures) effectively decrease the overall HVAC cooling load at those times.

This project took place in PG&E's Climate Zone 12, which is located just east of the San Francisco Bay Area.[9] California statewide utility data and building energy simulations have been used to derive HVAC interactive factors for building types and locations throughout the state. As Table 4 indicates, for this climate zone and building type, the utility HVAC interactive factor assumptions are that:

- Each kWh of lighting energy saved through the MR16 retrofit is reduced by 6%, and gas usage is increased slightly, due to overall increases in HVAC heating needs
- Each kW of peak demand reduction is increased by 33% due to reduced cooling demand during the peak period.

**TABLE 4 – INTERACTIVE FACTORS[10]**

| | Independent Values | | | HVAC interactive factors | | |
|---|---|---|---|---|---|---|
| **Measure Type** | **Building Vintage** | **Building Subsector** | **Climate Zone** | **Energy** (kWh/kWh) | **Demand** (kW/kW) | **Gas** (therm/kWh) |
| CFL | Existing | Grocery | 12 | 0.94 | 1.33 | -0.0125 |
| CFL | Existing | Retail | 12 | 1.06 | 1.23 | -0.0064 |

[9] For a full description of California's climate zones and building design strategies for each climate zone, see: http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zone_12.pdf

[10] CFL is listed as the proxy measure type because there is not a specific value for interactive factors of MR16s.

Source: DEER 2010.

# ASSESSMENT OBJECTIVES

### Scaled Field Placement: Definition and Intent

A scaled field placement is focused on evaluating product performance in multiple sites or applications for potential broader market adoption. Scaled field placements allow stakeholders with adoption influence, in this case a major grocery chain, to experience the benefits of an energy efficiency or demand response measure. This Emerging Technology project is categorized as a "Scaled Field Placement" due to its performance assessment across multiple applications within a single Safeway store.[11] A second component of the study was to understand how a large retail grocery chain such as Safeway evaluates energy efficiency opportunities, makes lighting fixture selections, and scales them across its many locations.

This will hopefully lead to broader, large-scale adoption of this measure, both by Safeway and other end-users using similar lighting applications. A scaled field placement intends to reduce adoption barriers such as information and search costs, performance uncertainties, as well as better understanding of organizational practices. For further information on Scaled Field Placements, see Appendix D.

As part of this study, the assessment focuses on three key objectives:

- Evaluating energy use and power quality characteristics of the Emerging Technology as compared to the existing technology and generating reproducible energy and demand savings data.
- Evaluating the lighting system performance of the Emerging Technology as compared to the existing technology.
- Assessing customer acceptance and selection of the Emerging Technology to better understand how utility programs can assist in increasing adoption of the Emerging Technology and / or similar products.

### Evaluating Energy Use and Power Quality Characteristics

The assessment objectives are to evaluate energy use and power characteristics, such as power draw, power factor, and total harmonic distortion across each MR16 lighting system. The lighting system is defined as the total number of fixtures in each grocery section, such as the wine, seasonal decoration, and deli sections. This approach accounts for changes in the total number of fixtures between the base and retrofit cases. Energy savings are thus calculated for each store area and aggregated at the store level. Maintenance savings are calculated on a per lamp basis and aggregated at the store level because maintenance is typically done across entire store sites. Energy savings are also calculated on a per fixture basis to provide a reference point for applications which do not include fixture reductions.

---

[11] At the beginning of the product assessment, Safeway planned to scale this product to 10 stores in Northern California in 2012, but limited this to two stores in 2012 with the goal of expanding to 150 stores in 2013.

### Evaluating lighting system performance and light quality

The objective of this report is to evaluate lighting system performance using photometric measurements and comparative photographs. In addition to comparing the base and measure case, this study also evaluates the Hornet's range of distribution capabilities by taking photometric measurements at the Hornet's narrowest and its widest beam angle. A second key objective is to use photos to provide a visual comparison of the base and retrofit case as well as the lighting distribution of the Amerlux product.

### Customer Satisfaction and Decision Making Survey

The objective of the customer satisfaction and decision making survey is to develop a detailed understanding of the customer decision making process and how utility programs can address adoption barriers. The survey focuses on four core areas:

- Understanding how Safeway evaluates and selects lighting products for use, with a specific focus on their experience with MR16 fixtures.
- Evaluating the role of utility incentive programs and identifying areas in which utility programs could address existing barriers to adoption.
- Identifying challenges in scaling technology to a large number of stores.
- Evaluating store employee satisfaction with the Hornet replacement fixture.

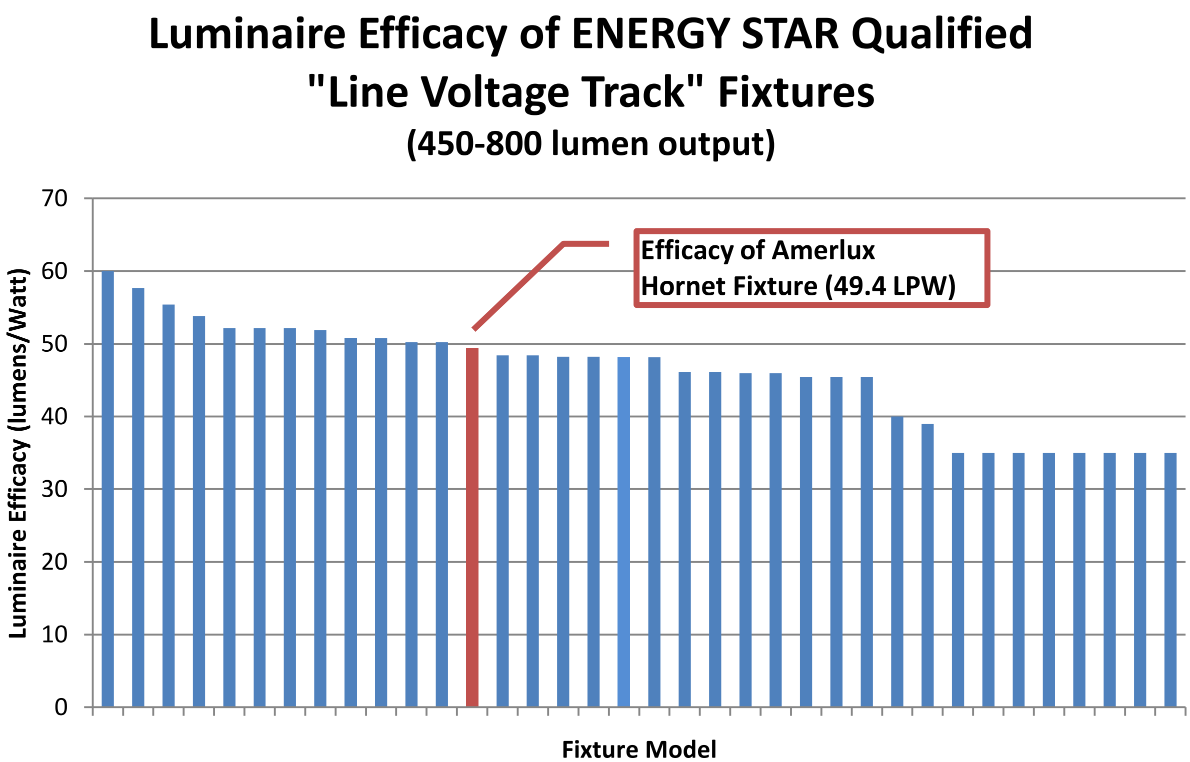
For additional detail on the customer satisfaction and decision making survey, please see Appendix A.

# TECHNOLOGY/PRODUCT EVALUATION

The Amerlux Hornet LED product was evaluated through a field installation located at a Safeway grocery store in the San Francisco Bay Area. In addition to on-site measurements, a core component of this study was a customer feedback and satisfaction survey completed by Safeway staff. This qualitative feedback on the installation, as well as details of the product selection process, would not have been available through a laboratory evaluation of the technology. The store selected for this study was equipped with halogen MR16 lamps, which represents the technology present in most Safeway locations. This particular store location was also appropriate because it is proximate to staff conducting the assessment, which decreased the cost associated with the evaluation. The assessment was completed by Energy Solutions staff with assistance from Safeway, Inc, Sylvania Lighting Services and Amerlux sales representatives. Energy Solutions has conducted a number of Emerging Technology assessments for a variety of clients, including utilities, efficiency organizations, and international organizations such as the United Nations. Energy Solutions previously conducted an Emerging Technology assessment of the first generation of MR16 products for PG&E in 2008 (Riker et al 2008). For more information about Energy Solutions' qualifications, visit www.energy-solution.com.

For this report, the Amerlux Hornet fixture was compared to other high efficiency LED directional lamp fixtures in the U.S. market, and the selected beam angle was compared against other possible configurations. Figure 6 shows the selected fixture's efficacy in lumens per watt, against other efficient LED fixtures on the ENERGY STAR Qualified Products List from November 16, 2012. The list is limited to the "Line Voltage Track" product category (primarily MR16 replacements), and filtered to only show products with similar lumen output as the Hornet fixture. The data displayed in Figure 6 contain products with a lumen output ranging from 450 lumens to 800 lumens. This range was selected based on findings from a study reviewing 50W MR16 LED replacement lamps in Europe (Navigant 2010). The Hornet performs in the top 30% of the listed fixtures.[12]

**FIGURE 6 – EFFICACY OF SELECTED FIXTURE RELATIVE TO COMPETING LED PRODUCTS**




[12] Note that the efficacy listed for the Hornet fixture on the Energy Star Qualified Product List (49 LPW) is lower than the LM-79 test data referenced earlier in this report (~54 LPW). The Hornet fixture is listed as "HORNET-15-LED-E-XX-XXXX-120-XXX-XXXX" to account for the wide range of product configurations, and the efficacy listed represents the lowest efficacy found across all possible configurations. Therefore, for the purposes of this report, we rely on LM-79 test data specific to the tested product configuration.

# TECHNICAL APPROACH/TEST METHODOLOGY

## FIELD TESTING OF TECHNOLOGY

This assessment was conducted at a Safeway store in the San Francisco Bay Area. Through discussions with Safeway, this site was selected due to its representative line and low voltage track layouts and halogen MR16 base case in multiple applications throughout the store. These applications include accent lighting for shelving and sign illumination. Although Safeway has an Energy Management System, these lights do not include any advanced control mechanisms such as dimming or scheduling, so the lights will remain at full power during store operating and stocking hours.

## TEST PLAN

In order to create a fair comparison between the base and retrofit case, all halogen MR16 fixtures lamps were relamped prior to the evaluation of the base case. Halogen MR16 lamps were installed and seasoned for roughly three days before taking measurements in accordance with LM-54-99, *IES Guide to Lamp Seasoning (IES 1999)*. Testing for the retrofit case was completed after roughly 50 hours of burn-in time.

In order to understand the product selection process for grocery and retail lighting, a product selection survey was developed. While the results reflect the criteria of only one organization, the survey is intended to provide insight into the energy efficiency decision making processes of large organizations, identify opportunities for utilities to address market adoption barriers, and provide feedback on the overall satisfaction of this particular product.

# METHODOLOGY

On November 9, 2012, Energy Solutions staff visited the Safeway site and took power measurements, photometric measurements, and photographic documentation for the existing base case halogen MR16 fixtures. The team returned on November 29, 2012 and performed the same measurements on the retrofit LED fixtures.

**Power Measurements**

On-site measurements were conducted for both the base case and the retrofit case using a PowerSight PS-3000. [13] All electrical work was completed by a certified electrician. The lighting systems monitored had a static configuration, with no dimming or other system

[13] Further information on the PS-3000 is detailed in the 'Instrumentation Plan' section.

changes enabled. The Safeway store is open 24 hours per day and the MR16 lamps are on continuously. Due to the consistent nature of the site's operating hours, instantaneous measurements were taken in lieu of long term power logging measurements without any significant loss to data quality.

All measurements were taken at line voltage (120V) upstream of transformers to make equal energy comparisons of the entire lighting system[14]. Voltage was measured by attaching the voltage probes to the hot and neutral line. Current was measured using a current transformer. Power factor and total harmonic distortion (THD) were also calculated by the PS-3000.

**Wine Section**

For the base case, the wine section had a central magnetic transformer supplying 12V power on low voltage tracks. A total of 24 halogen lamps were on six circuits, averaging four 50W lamps on each circuit. All measurements for the base case were made on a single circuit and extrapolated for the remaining circuits. Electricians used a scissor lift to access the line voltage above the transformer, located above the drop ceiling. For the retrofit, the central transformer was removed, and the low voltage track was replaced with a line voltage track. Sixteen 15W LED fixtures were placed the track on one 20A circuit.

**Seasonal Decoration Section**

In the seasonal decoration section, six halogen fixtures with integrated electronic transformers were located on a line voltage track at 120V. Electricians used a stepladder and took readings of the entire track. For the retrofit, four LED fixtures were installed on the existing tracks and power measurements were taken by the same process.

**Deli Section**

Due to access issues, no power measurements were taken in the deli section. A total of 8 halogen fixtures in the base case were replaced with 6 LED fixtures on the existing tracks in the retrofit. The performance of the fixtures in the Deli section is expected to be consistent with results of the Seasonal Display as both areas contained the same halogen fixtures with integrated electronic transformers.

**Photometric Measurements**

Illuminance and correlated color temperature measurements were taken for both the base and retrofit case.[15] Due to the specific retail environment, the team developed a custom lighting monitoring plan in consultation with Safeway and PG&E to evaluate lighting distribution (see Appendix B for further detail on the monitoring plan).

Illumination measurements were taken in all three areas of the lighting retrofit: the wine section, seasonal decoration and the deli sections. Measurements in each location were taken on a regularly distributed grid as detailed in Appendix B. These measurements were

[14] For the central magnetic transformer, we took measurements above and below the transformer to establish transformer efficiency, which was 92%.

[15] The retrofit case included two sets of measurements using the widest and narrowest optical lens to obtain the range of distribution for the Hornet product.

developed to account for differences in fixture spacing between the base and retrofit case. Measurements were taken directly underneath lamps and at the midpoint between lamps to obtain maximum and minimum illuminance values for each plane of interest. For the wine section and seasonal decoration sections, halogen lamps were spaced 24 inches on center, therefore measurements were placed every 12 inches. LED retrofit fixtures were spaced 36 inches on center, therefore measurements are spaced 18 inches apart. Measurements taken on the deli signs were taken on a smaller measurement grid against the sign surface. Due to differences in size of the signs and relatively small size of the signs, relative positions (top, middle, base) were used rather than absolute distances.

For the wine and seasonal decoration sections, each row of measurements was taken at each shelf height, starting at the floor level. The floor measurements were taken horizontally, with the light meter facing the ceiling. All other measurements were taken vertically with the light meter facing away from the shelf merchandise, towards the light source. For the deli section, all measurements were taken vertically with the light meter facing away from the shelf merchandise, towards the light source.

Color temperature measurements were taken in all three locations: the wine section and seasonal decoration measurements were taken at a height of five feet, located within the beam angle, and the deli sign measurements were taken against the sign face within the beam angle. The seasonal decoration is located next to exterior windows of the store, so measurements were taken prior to sunrise to limit the intrusion of sunlight on the measurements.

### Photographs

Photographs were taken of the base case and retrofit to provide a qualitative comparison of the visual impact resulting from the change in the lighting system. For each pair of photographs, a Canon 40D DSLR used identical camera settings (shutter speed, f-stop, and ISO). The photographs were used to visually characterize lighting distribution across shelves and signage, and determine the presence of hot spots and darker, under-lit areas.

### Satisfaction Survey

To develop the satisfaction survey, Energy Solutions conducted an initial interview with key decision makers within Safeway to develop an understanding of their internal decision making structure and how energy efficiency opportunities are evaluated. Based on this initial interview, the project team developed a survey which covered the following topics:

- Existing Operation
- Financial Metrics when considering energy savings opportunities
- Product Evaluation and fixture selection process
- Evaluating the impact of utility programs and external agencies in the selection process
- Scaling up the retrofits across all Safeway stores
- Demand Response and Dimming
- Employee response to lighting retrofit

Based on the feedback from this interview, Energy Solutions conducted two follow up interviews with Safeway representatives to discuss survey responses in further detail.

## INSTRUMENTATION PLAN

Power measurements were obtained using a Summit Technologies PowerSight PS-3000. Photometric measurements were obtained using a Konica Minolta CL-200. Both tools were obtained on a loan from the PG&E Pacific Energy Center Tool Lending Library, and were initially checked to ensure they were functioning correctly. Instrumentation specifications are provided in Table 5 below.

TABLE 5 – STUDY INSTRUMENTATION

| Variable | Illumination | Correlated Color Temperature | Power, Power Quality | Current | Voltage |
|---|---|---|---|---|---|
| **Instrument** | Konica Minolta CL-200 | Konica Minolta CL-200 | PowerSight PS-3000 | PowerSight PS-3000 | PowerSight PS-3000 |
| **Units** | Foot-candles | Kelvin | Watts, PF, THD | Amps | Volts |
| **Measurement Range** | 0.01-9,999 fc | 0.5 fc or above | Not given | 1mA-5000$A_{rms}$ | 1-15,000 $V_{rms}$ |
| **Accuracy (%)** | ±0.002 | ±2%±1 digit of displayed value | ±1% | ±0.5% | ±0.5% |
| **Response time** | 0.5 seconds | 0.5 seconds | 16 µsec | 16 µsec | 16 µsec |
| **Last Calibrated** | 2011 | 2011 | 2011 | 2011 | 2011 |

# RESULTS

### Power Measurements

Power draw for both the halogen and LED lamps was within 5% of the nominal fixture wattage. For the halogen fixtures, per fixture power consumption was dependent on the type of transformer used. Fixtures using the large magnetic transformer used 3.5W (7% of nominal) more power than the halogen fixtures with electronic ballasts.

Power factor was lower for the LED fixtures than the halogen fixtures but was still well within acceptable limits. The total harmonic distortion for the LEDs was consistent with halogen fixtures with small electronic ballasts but greater than the halogen fixtures with a central magnetic transformer. Due to the presence of a central transformer in the wine section for the halogen fixtures, the measurement was limited to one 4-lamp circuit. Since the LED retrofit fixtures have integrated drivers, the measurements were taken on the entire section. The total number of fixtures was also reduced overall for the retrofit.

Additional measurement data which was not used for the final report is provided in Appendix C. [16]

## TABLE 6 – POWER MEASUREMENTS

| **Wine Section** | Halogen | LED |
|---|---|---|
| Average power/fixture (Watts) | 49.8 | 14.3 |
| Average current/fixture (Amps) | 0.45 | 0.12 |
| Power Factor | 1.00 | 0.98 |
| Total Harmonic Distortion | 6% | 14% |
| # of fixtures on circuit | 4 | 16 |

| **Seasonal Decoration** | Halogen | LED |
|---|---|---|
| Average power/fixture (Watts) | 46.3 | 14.5 |
| Average current/fixture (Amps) | 0.42 | 0.15 |
| Power Factor | 0.99 | 0.87 |
| Total Harmonic Distortion | 14% | 14% |
| # of fixtures on circuit | 6 | 4 |

**Illuminance Measurements**

Table 7 - Table 9 below show illuminance measurements of each store area and are colored using a gradient where the highest values have the darkest coloration and the lowest values have the lightest. The colors do not correspond to absolute values, but rather relative percentages of the maximum illuminance found within each comparison group of measurements (before and after) such as the red wine section. For example, the highest and lowest recorded measurements in the red wine section, both for the halogen and LED, were 112.6 and 10.6 footcandles, and were both recorded under the halogen lighting. The Red Wine – LED measurements were concentrated in the middle of this range. The color gradient provides a visual depiction of the lighting distribution of each system, where tables with relatively consistent coloring indicate more even illumination levels and a lower contrast ratio. Tables with redder or whiter cells indicate a more uneven distribution, resulting in hotspots and under-lit areas, respectively. It is important to re-iterate that the base and retrofit case do not provide a perfect comparison due to the difference in beam angles. The existing halogen fixtures used a 35° beam angle, and the retrofit fixture used a 60° beam angle. Therefore, the substantial difference in beam spread is due to the different beam angles employed in the base and retrofit case.

[16] During the initial site visit, an extra set of illumination data was taken in the white wine section, but was determined to be redundant to the data collected in the red wine section. Excluded data can be seen in Appendix C: Extra Data.

## Table 7 – Wine Section Illuminance Measurements (Footcandles)

| Sample color gradient | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | 10% | 0% |

**Red Wine – Halogen**

| | Lamp | | Lamp | | Lamp |
|---|---|---|---|---|---|
| Shelf 4 (72") | 80.9 | 42.9 | 83.8 | 112.6 | 87.8 |
| Shelf 3 (57") | 45.1 | 33.2 | 52.5 | 70.3 | 64.3 |
| Shelf 2 (42") | 17.1 | 16.7 | 24.0 | 30.4 | 28.8 |
| Shelf 1 (27") | 10.6 | 11.6 | 12.3 | 13.0 | 11.8 |
| Floor (0") | 11.8 | 13.5 | 13.2 | 13.5 | 13.0 |

**Red Wine - LED**

| | Lamp | | Lamp | | Lamp |
|---|---|---|---|---|---|
| Shelf 4 (72") | 63.1 | 58.4 | 45.5 | 52.1 | 60.3 |
| Shelf 3 (57") | 57.1 | 59.8 | 53.4 | 51.0 | 50.3 |
| Shelf 2 (42") | 37.2 | 40.4 | 40.6 | 38.2 | 35.1 |
| Shelf 1 (27") | 27.1 | 26.1 | 26.2 | 27.1 | 27.6 |
| Floor (0") | 24.6 | 25.7 | 27.2 | 27.1 | 27.6 |

## Table 8 – Seasonal Decoration Illuminance Measurements (Footcandles)

**Halogen**

| | | Lamp | | Lamp |
|---|---|---|---|---|
| Shelf 4 (72") | 37.0 | 47.7 | 45.0 | 37.8 |
| Shelf 3 (48") | 20.7 | 31.7 | 27.4 | 30.4 |
| Shelf 2 (36") | 13.7 | 21.0 | 19.5 | 18.3 |
| Shelf 1 (24") | 10.1 | 14.1 | 13.7 | 13.6 |
| Floor (0") | 17.6 | 19.1 | 22.2 | 20.1 |

**LED**

| | | Lamp | | Lamp |
|---|---|---|---|---|
| Shelf 4 (72") | 54.0 | 50.3 | 47.1 | 50.6 |
| Shelf 3 (48") | 26.0 | 25.4 | 26.6 | 29.6 |
| Shelf 2 (36") | 16.4 | 19.0 | 19.0 | 21.3 |
| Shelf 1 (24") | 14.2 | 14.1 | 14.9 | 15.2 |
| Floor (0") | 23.2 | 28.4 | 29.5 | 22.6 |

## Table 9 – Deli Sign Illuminance Measurements (FootCandles)

**Tall Sign - Halogen**

| | left | middle | right |
|---|---|---|---|
| Top | 92.7 | 166.9 | 60.41 |
| Upper third | 90.5 | 130.1 | 72.6 |
| Lower third | 58.7 | 75.9 | 31.4 |
| Base of sign | 32.5 | 37.6 | 19.4 |

**Tall Sign - LED**

| | left | middle | right |
|---|---|---|---|
| Top | 42.2 | 67.4 | 72.3 |
| Upper third | 43.8 | 77.9 | 69.5 |
| Lower third | 30.7 | 62.1 | 57.2 |
| Base of sign | 17.2 | 20.1 | 18.1 |

**Wide sign - Halogen**

| | left | middle | right |
|---|---|---|---|
| Top | 146.4 | 335.5 | 145.0 |
| Middle | 174.0 | 173.0 | 139.0 |
| Base of sign | 29.0 | 21.2 | 52.1 |

**Wide Sign - LED**

| | left | middle | right |
|---|---|---|---|
| Top | 41.7 | 100.8 | 63.1 |
| Middle | 45.4 | 59.5 | 55.2 |
| Base of sign | 15.5 | 24.7 | 29.3 |

In addition to illuminance comparisons between the retrofit and base case, Energy Solutions staff worked with an Amerlux sales representative to take measurements of a narrow 15° spot beam and a 60° linear spread. These two configurations, which are listed below in Table 10, represent the broadest and narrowest angles available for the product, with additional configurations (28° Flood and 45° Wide Flood) falling in between these two extremes. The max/min ratio for the linear spread is 2.6, and the spot configuration is 16.2.

## TABLE 10 - LED CONFIGURATION COMPARISON (FOOTCANDLES)

**Red Wine - LED Linear Spread**

| | Lamp | | Lamp | | Lamp |
|---|---|---|---|---|---|
| Shelf 4 (72") | 63.1 | 58.4 | 45.5 | 52.1 | 60.3 |
| Shelf 3 (57") | 57.1 | 59.8 | 53.4 | 51.0 | 50.3 |
| Shelf 2 (42") | 37.2 | 40.4 | 40.6 | 38.2 | 35.1 |
| Shelf 1 (27") | 27.1 | 26.1 | 26.2 | 27.1 | 27.6 |
| Floor (0") | 24.6 | 25.7 | 27.2 | 27.1 | 27.6 |

**Red Wine - LED spot**

| | Lamp | | Lamp | | Lamp |
|---|---|---|---|---|---|
| Shelf 4 (72") | 220.0 | 20.3 | 222.0 | 22.6 | 209.2 |
| Shelf 3 (57") | 127.6 | 24.4 | 198.0 | 31.1 | 171.9 |
| Shelf 2 (42") | 25.4 | 29.1 | 129.6 | 38.8 | 34.6 |
| Shelf 1 (27") | 13.7 | 22.1 | 64.0 | 30.2 | 18.0 |
| Floor (0") | 17.8 | 18.1 | 24.3 | 23.0 | 21.7 |

### PHOTOGRAPHIC COMPARISON OF BASE CASE AND RETROFIT CASE

The photographs provide a visual comparison of the base case and retrofit case, which is described below. It is important to re-iterate that the base and retrofit case have different beam angles, and so it is difficult to make a direct comparison between the halogen and LED technologies given the different beam angles. As previously discussed, the purpose of the photographs is to demonstrate the ability of the LED fixture to provide comparable lighting performance to a 50W halogen MR16 and a high level of controllability. The base case had a number of hot spots and underlit areas, which was primarily due to a narrower beam angle than the retrofit. The retrofit case reduced the presence of hot spots and underlit areas, providing even distribution and acceptable light levels across the product shelves. The color temperature for the LED fixtures appeared to be slightly higher than the halogens.

The comparison of the Hornet's  spot and linear spread lenses indicate that the fixture is capable of both providing a narrow, well-defined beam angle and a broad spread with an even distribution.

**FIGURE 7 – WINE SECTION COMPARISON (VERTICAL)**

FIGURE 8 – WINE SECTION COMPARISON (HORIZONTAL)


FIGURE 9 – SEASONAL DECORATION SECTION COMPARISON


## FIGURE 10 – DELI SIGN COMPARISON


FIGURE 11 – LED SPREAD AND SPOT COMPARISON


### COLOR TEMPERATURE

In all store areas, both the LED and halogen fixtures had color temperature values that were slightly higher than advertised on the product specification sheets. This can be attributed to the presence of the 4100K ambient lighting from linear fluorescents.

### TABLE 11 – COLOR TEMPERATURE MEASUREMENTS

| Correlated Color Temperature (Kelvin) | | |
|---|---|---|
| | **Halogen** | **LED** |
| **Wine** | 2761 | 3021 |
| **Seasonal Decoration** | 2717 | 3024 |
| **Deli** | 2866 | 3021 |

# DATA ANALYSIS

**Analysis of Illuminance Measurements**

The base case and retrofit conditions can be compared using a maximum to minimum ratio, which gives a single metric for the total range of lighting values. A lower value means more consistent, uniform light levels. As shown in Table 12, the LED fixture has more evenly distributed lighting in all applications in the store. This improvement is primarily due to a wider beam angle. It is expected that a halogen fixture with a similar beam angle would have comparable performance.

### TABLE 12 – ILLUMINANCE MAX/MIN RATIOS

| | Illuminance Max/Min Ratio | | | |
|---|---|---|---|---|
| | **Wine** | **Seasonal Decoration** | **Deli Tall sign** | **Deli Wide sign** |
| Halogen | 10.6 | 4.7 | 8.6 | 15.8 |
| LED | 2.5 | 3.8 | 4.5 | 6.5 |

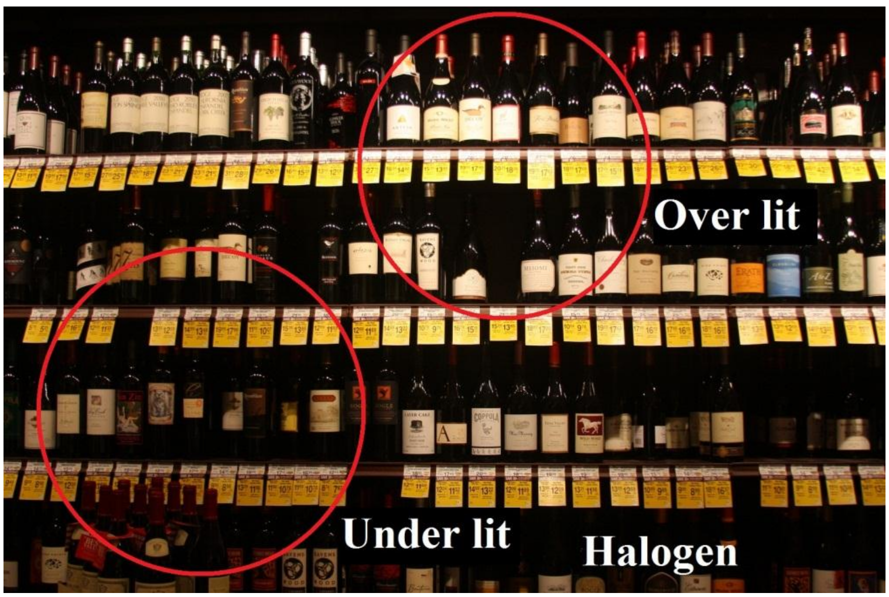
In addition to measuring the range of values, or lighting contrast, the average of both the retrofit and base case measurements can be compared. This information is included in Table 13. Increases in overall illumination can be seen for the wine and seasonal decoration sections, though less light is present on average for the deli sign. In each section, these changes improved overall lighting quality.

**TABLE 13 – AVERAGE ILLUMINATION**

| Average Illuminance (fc) | Halogen | LED |
|---|---|---|
| Wine Section | 36.6 | 40.4 |
| Seasonal Decoration | 22.8 | 27.4 |
| Deli Sign - Tall | 72.4 | 48.2 |
| Deli Sign - Wide | 135.0 | 48.0 |

The high contrast measured in the halogen base case is depicted in Figure 12 below. The narrow beam angle used created alternating over lit and underlit areas. Using a 60° beam angle, the Hornet fixture achieved a max/min ratio under three, which is ideal for shelf lighting.

**FIGURE 12 – OVER LIT AND UNDERLIT AREAS WITH HALOGEN LIGHTING WITH A 35° BEAM ANGLE**




**Safeway Fixture Selection and Decision Making Survey Results**

Safeway began exploring potential MR16 retrofit option solutions in 2008 when the MR16 DOE CALiPER report was released, and actively participated in the DOE's Commercial Building Energy Alliance. They relied on external agencies, such as DOE, DesignLights Consortium (DLC), ENERGY STAR, and utility programs to provide accurate product characterizations and establish LED minimum performance requirements. Safeway's process began with an analysis of product specification sheets and whitepaper analysis of potential energy and cost savings. If the fixture passed a whitepaper analysis, it was evaluated in a small demonstration test in a Safeway store. They relied on external agencies for evaluation and verification of product requirements.

Based on their experience and reviews of demonstration tests (DOE 2008, Riker et al 2008), the first generation "GEN 1" products did not have high enough efficacy or reliable color temperatures to meet Safeway's selection criteria. In addition, the CALiPER testing showed high failure rates (DOE 2008). The second generation, "GEN 2" LED chips had substantially higher efficacy and reliability. The lessons learned from testing GEN 1 lamps helped formulate their fixture selection criteria.

From a technical perspective, Safeway's selection criteria required a high-efficacy fixture with reliable, warm color temperature that would increase overall light levels and improve uniformity, eliminating both over lit 'hot spots' and underlit 'dark spots'. To ensure long-term reliability, Safeway required that the LED chip be from a major chip manufacturer with at least a six year warranty, and that the fixture meet both Energy Star and utility incentive requirements.

Aesthetics were also important product consideration in Safeway's selection criteria. They required that the fixture be an attractive, non-intrusive with a small form factor. In addition, Safeway required that the light emanate from a single source and that the fixture not be comprised of small LEDs which create multiple light beams and shadows.

From a financial standpoint, Safeway required the total retrofit package to have an attractive return on investment (ROI) and simple payback of less than 1.5 years[17], yielding a minimum of 30% energy savings, 50% maintenance savings and a 20% reduction in fixture count.[18] In addition, the fixture needed to have an affordable initial cost. According to Safeway, utility financial incentives played a moderately important role in their decision to retrofit the fixtures, but were secondary to long term energy and maintenance savings. However, the importance of a utility incentive increases with the product's initial costs. Based on estimated fixture and installation costs, the LEDA incentive reduced the initial cost of the Amerlux fixture cost by roughly 15%.

Once the product has been successfully tested and meets Safeway's performance criteria, it is phased in across other stores and becomes integrated into the construction design specifications for new Safeway stores. Safeway plans to scale this 150 of its California stores between Q1-Q3 2013, all of which will be located in utilities territories that offer commercial LED incentive programs. A key challenge of scaling is incorporating this plan into existing store remodels, as well as standalone lighting retrofits. Additional lighting measures, including biax lamps and recessed fixtures may be incorporated into these projects, based on the availability of rebates.

### Customer Satisfaction Survey Results

The Liquor Department Manager, responsible for the wine section where the LEDs were installed, was very satisfied with the new lighting system, noting that the new lighting significantly improved the retail atmosphere and would strongly recommend that the company adopt this retrofit to all other stores. The manager stated that it produced a "softer light" with significantly less glare. He also noted that the heat from the halogen fixtures could be sensed by customers reaching for products on the top shelf, which occasionally resulted in a customer complaint. After the installation of the LED fixtures, the manager had not received a customer complaint due to this heating issue.

---

[17] Based on Energy Solutions' discussions with industry partners, most companies require a payback of two years or less for efficiency measures.

[18] Payback and maintenance savings goals are based on a per fixture cost only, and do not include installation costs.

**Safeway's experience with external agencies and utility energy efficiency programs.**

Overall, Safeway had a very positive experience with external agencies and found them very helpful in providing information relevant to their decision making process. This included DOE, CALiPER, ENERGY STAR, the DLC, and utility programs.[19] These agencies provided Safeway with sufficient data and understanding of the LED market. One concern that Safeway highlighted was the perceived lack of a disposal policy and appropriate end of life strategy for integrated LED fixtures.

Overall, Safeway felt that PG&E's third party LED Accelerator (LEDA) Program was very helpful in addressing information and ensuring product quality. Safeway was very satisfied with the level of program support and felt that the utility program representatives made a strong effort to understand their long-term efficiency priorities and needs, and in turn responded by offering programs that fit these needs. Safeway currently participates in Demand Response programs in both PG&E and SCE territory, which include store lighting. Once the Hornet is integrated throughout its California stores, Safeway will consider integrating the fixture's dimming capabilities in future demand response programs.

## ENERGY SAVINGS AND ECONOMIC IMPACT

Energy savings were calculated both on a per-fixture (i.e. one-to-one replacement) basis, and as a store-wide retrofit across all product sections. The switch to a wider beam angle allowed the store to reduce the total number of installed fixtures and generate additional savings. Results of these calculations can be seen in 14. Since this store is open 24 hours, it is assumed that the lamps are operating 8,760 hours per year (24 hours per day, 365 days per year). Cost savings were determined using the most current PG&E E19 rate schedule, which is approximately $0.14/kWh.[20] Energy and cost savings for the whole store are based on a fixture reduction from 62 to 45 fixtures. Using these inputs, the retrofit results in a 69% reduction in peak demand, energy usage and costs on a per-fixture basis. On a storewide basis, the retrofit achieved a 77% reduction in peak demand, energy usage, and costs, including fixture reductions. When including interactive factors, the retrofit achieved a 103% reduction in peak demand, 73% reduction in energy usage, and a 67% in cost savings. For a detailed discussion of interactive factors, see Table 4.

**TABLE 14 – ANNUAL ENERGY AND COST SAVINGS PER FIXTURE (ONE-TO – ONE)**

| | Halogen | LED | Savings | % Reduction |
|---|---|---|---|---|
| Demand (Watts)[21] | 46.1 | 14.4 | 31.7 | 69% |
| Energy (kWh/year) | 404 | 126 | 278 | |
| Energy cost ($/year) | $56 | $18 | $39 | |

[19] These utility programs include PG&E, Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), Sacramento Municipal Utility District (SMUD) and Xcel Energy's program for Denver.

[20] PG&E E19 rate schedule last updated July 1, 2012. For a full description of PG&E's rate schedules, visit: http://www.pge.com/tariffs/rateinfo.shtml

[21] Demand figures are based on measured values rather than product specification sheets, and therefore exact savings values may differ slightly.

## TABLE 15 – ANNUAL ENERGY AND COST SAVINGS FROM STORE-WIDE MR16 RETROFIT[22]

| | Halogen | LED | Savings | % Reduction |
|---|---|---|---|---|
| Demand (Watts) | 2,858 | 648 | 2,210 | 77% |
| Energy (kWh/year) | 25,038 | 5,676 | 19,361 | |
| Energy cost ($/year) | $3,475 | $788 | $2,687 | |
| Number of fixtures | 62 | 45 | 17 | 27% |

## TABLE 16 – ANNUAL ENERGY AND COST SAVINGS FROM STORE-WIDE MR16 RETROFIT (INCLUDING INTERACTIVE FACTORS)

| | Store-Wide retrofit with Interactive Factors | % reduction |
|---|---|---|
| Peak Demand Reduction (Watts) | 2,939 | 103% |
| Energy Savings (kWh/year) | 18,200 | 73% |
| Energy Savings (therms/year) | -242 | -- |
| Cost Savings ($/year) | $2,344[23] | 67% |

In addition to energy savings, a more complete lifecycle cost analysis for the halogen and LED retrofits includes the cost associated with the materials and labor for lamp replacements, as shown in 17. Over the 50,000 hour life of the LEDs, halogen lamps must be replaced an estimated 12 times (12 x 4,000 hour rated life = 48,000 hours). Lamp and labor costs are estimates based on available industry information.

## TABLE 17 – MAINTENANCE LIFE CYCLE COST ANALYSIS FOR HALOGEN AND LED FIXTURES[24]

| | Halogen | LED |
|---|---|---|
| Lamp or fixture cost (per fixture)[25] | $10 | $150 |

---

[22] Storewide energy and demand savings are greater due to a 27% reduction in installed fixtures.

[23] Cost savings estimates include additional natural gas costs, and are based on PG&E's Large Commercial Natural Gas Rate Schedule: http://www.pge.com/tariffs/rateinfo.shtml

[24] Costs were compared on the basis of a 50,000 LED lifetime.

[25] Based on Amerlux quote of $150 per 15W Hornet fixture. This cost does not include utility program incentives.

| | | |
|---|---|---|
| LEDA incentive ($ per fixture) [26] | -- | $16 |
| Installation labor cost (per fixture) | $10 | $80[27] |
| Lamp life (hours) | 4,000 | 50,000 |
| Number of installs | 12 | 1 |
| Number of fixtures | 62 | 45 |
| Total cost ($, assuming 5% discount rate) | $14,096 | $9,639 |
| Average Annual Cost (assuming 5% discount rate) | $2,473 | $1,691 |
| Annual Maintenance Cost Savings | -- | **$782** |
| Maintenance Cost savings (over LED lifetime) | -- | **$4,456** |

**TABLE 18 – LIFE CYCLE COST ANALYSIS FOR HALOGEN AND LED RETROFIT**

| | |
|---|---|
| Annual store energy cost savings ($ per year @ $0.14/kWh | $2,687 |
| Annual store maintenance savings ($ per year) | $782 |
| Total store savings ($ per year) | $3,468 |
| Life of LED fixtures (years)[28] | 5.7 |
| Total energy cost savings ($ per LED lifetime) | $15,337 |
| Maintenance cost savings ($ per LED lifetime) | $4,456 |
| **Total store savings per LED lifetime** | **$19,793** |
| **Return on Investment (ROI)[29]** | **105%** |

On a one-to-one fixture replacement basis, estimated simple payback based on energy savings alone is 3.5 years not including installation costs, and 5.6 years including installation costs. However, because the Hornet fixture provides a comprehensive lighting solution including a reduction in total number of fixtures, economic calculations should account for these fixture reductions. Accounting for fixture reductions, the estimated simple payback is to 3.6 years, not including maintenance savings. When including maintenance savings, the store achieved a 2.8 year payback, which also includes installation costs. It should be noted that installation is roughly 60% of the fixture cost, significantly lengthening payback. Payback can be significantly reduced if installation costs can be incorporated into scheduled maintenance retrofits. This resulted in a total savings of $19,793 over the estimated 5.7 year lifetime of the LED, or a 105% ROI for that same period.

# EVALUATIONS

[26] Based on LEDA utility incentive of $16 per fixture based on LEDA Tier 0 incentive rate of $300/kW.

[27] Installation estimate includes removal of existing halogen fixtures and installation of LED fixtures.

[28] LED fixture lifetime assumes 24/7 operation, based on existing store hours.

[29] ROI is calculated as the (Gain from investment – Cost of investment) / (Cost of investment).

**Energy, Peak Demand and Cost Savings:**

Based on the results of this scaled field placement, the selected Amerlux Hornet fixture proved that LED replacements of MR16 lamps are effective in creating desired lighting effect while reducing power demands and creating energy savings.

On a per fixture basis, the Hornet fixture achieved 69% savings in demand and energy use. On a store level, the Hornet fixture achieved 77% savings in peak demand and energy use and 35% maintenance savings, which accounts for fixture reductions. These savings values are based on 24/7 operation, and so the results should be scaled appropriately when applying these values to other environments. Scaled to 150 stores, this retrofit will result in annual energy savings of 3.75 GWh and a 429 kW reduction in peak demand.[30] Including interactive factors, the retrofit would result in annual energy savings of 3.52 GWh and 571 kW reduction in peak demand.

**Lighting Performance**

The Hornet fixture improved lighting quality over the base case by decreasing contrast levels and removing hotspots and underlit areas, primarily through the use of a wider beam angle. The 21W Hornet fixture demonstrated a high level of controllability while achieving CBCP levels equivalent to a 50W MR16 fixture if configured at an equivalent beam angle. However, the 15W fixture has lower CBCP levels than a halogen MR16 fixture. The 15W fixture is considered a sufficient replacement for a 50W halogen MR16, except in applications which require very high light intensity, where the 21W fixture is best suited replacement. This product's interchangeable lenses allow users to produce dramatically different lighting effects using the same lamp, and is especially well suited for spaces with dynamic lighting requirements such as retail or art galleries. This feature represents a significant improvement in lighting control over both existing halogen MR16 lamps and LED MR16 replacement lamps, and could dramatically reduce maintenance and material costs for applications where spaces are relamped simply to achieve different lighting effects.

**Results from the Feedback and Satisfaction Survey**

Safeway representatives were very satisfied with the energy and maintenance savings, and lighting quality achieved by the Hornet fixture. The comparatively high initial cost of the Hornet fixture remains the most significant adoption barrier. Utility incentives can continue to reduce the initial cost and improve the economics. However, when considering the Hornet or similar fixtures as a comprehensive lighting solution instead of a one to one lamp replacement, the significant reduction in fixtures dramatically reduce the payback period and increase overall energy and maintenance savings.

External programs which provide product assessment and establish minimum performance requirements play a significant role in assisting organizations select high quality LED products. LED lamp performance and high product quality is critical to achieving long-term energy savings, and therefore setting quality standards is a core component of an incentive program. For organizations which lack internal lighting resources or lighting experts, an

[30] This is likely a conservative estimate since the study site is slightly smaller than a typical Safeway store. However, based on similar fixture reduction rates achieved in the second store, which was much larger, it is assumed that similar fixture reduction rates can be achieved at all stores regardless of size and fixture counts.

external agency or guide will significantly reduce search and information costs as well as the chance of a bad experience with new LED technology.

# RECOMMENDATIONS

The fixture evaluated provides significant energy and maintenance benefits while providing high level of controllability typically desired in retail, hospitality, and grocery sectors. The integrated fixture design was helpful in that it mitigated any potential issues of compatibility with line and low voltage tracks and transformers.

We recommend that PG&E integrate this fixture and any other similar fixtures into future commercial advanced LED programs. In addition to achieving energy savings of over 70%, the retrofit achieved a 103% reduction in peak demand when including interactive factors. This fixture, and others which meet similar product criteria, has the potential to dramatically reduce utility peak demand because of the high demand interactive factors associated with retail and grocery applications. Furthermore, its dimming capabilities allow for integration with future utility Auto Demand Programs to provide additional peak demand savings.

The Hornet fixture is one of the first suitable 50W MR16 replacements, and there still remain a number of market barriers which utility programs can help address. While Safeway has a highly refined product selection process and a high degree of internal lighting expertise, there are many companies that lack the internal expertise that could significantly benefit from utility programs which provide detailed product information and established qualification criteria. This effort would significantly reduce information and search costs for companies evaluating lighting options. While energy and maintenance savings are the primary drivers of energy efficiency decisions, incentives continue to play an important role in increasing market adoption of LED fixtures and encouraging companies to make energy efficient decisions. Of the150 stores which Safeway plans to retrofit from halogen MR16 fixtures to integrated LED fixtures in 2013, 100% of them are in a utility territory which has an existing commercial LED incentive program. This strongly suggests the importance of a commercial LED incentive program in addressing barriers to the widespread market adoption of high quality LED fixtures in track lighting applications.

We recommend that PG&E conduct a follow-up Phase II study in late 2013 once Safeway has installed the Amerlux fixture across 150 installations in California. This study would focus on the longer-term product performance, lessons learned in the process of scaling up, comparisons of the base and retrofit cases using similar beam angles, and additional retrofit opportunities for the Hornet fixture, including wall-wash and recessed applications.

# APPENDICES

## Appendix A: Customer Satisfaction and Decision Making Survey

**Customer Satisfaction and Decision Making Survey**
As part of this Emerging Technologies study, PG&E is evaluating the performance of the Amerlux LED MR16 fixture. In addition to technical lighting and power measurements, PG&E would also like to understand Safeway's decision making process for both fixture selection and scaling these fixtures across many stores. This information will provide insight on how PG&E can refine future program offerings to best suit the needs of its large retail customers.

The results of this survey will help inform the ET Demonstration report. Some of this information may be included in the public report. We understand that certain areas may contain sensitive or proprietary information that Safeway does not wish to publish or would prefer to discuss on a more general level. For each question, please note any confidentiality concerns or specific items you would like to omit for the external report. As stated in the customer agreement, Safeway will have one week to review the rough draft in December and request any changes to the report before it is made public.

1. **Existing Operation**
   a. What are Safeway's normal operating hours, excluding stores operating 24/7?

   b. What fraction of Safeway stores are open 24 hours? Do all stores that are not on a 24/7 schedule have identical hours?

   c. How many holidays per year have amended store hours? Do holidays impact stores that are open 24/7?

   d. Please describe any additional activities that impact the operating hours of MR16s, such as stocking and maintenance.

   e. How often do you conduct scheduled replacements where you relamp existing MR16 halogen fixtures? Roughly what fraction of these lamps had pre-mature failures that require spot-replacement? How often do you perform spot replacements?

   f. What is your expected relamp frequency for LEDs?

   g. What is the estimated cost of relamping a halogen MR16 for a scheduled, store-wide replacement? Spot replacement?

h. What is your average electric utility rate ($/kWh)?

i. Do you expect any other changes to costs from adopting a new LED fixture, such as installation time?

2. **Financial Calculations**
   a. What financial metrics do you consider when evaluating the cost-effectiveness of an energy efficiency measure (EEM)?

   b. Is there a minimum payback time required for Safeway to implement an EEM?

   c. What costs do you consider into your calculations?

   d. Do you consider HVAC savings due to the reduced heat load into your calculations?

3. **Fixture Selection Process**
   a. What were the key factors that influenced your decision to install LED MR16 fixtures?
      i. Energy/cost savings
      ii. Lamp replacement time/cost savings
      iii. Light distribution
      iv. Other

   b. What were your key concerns about switching to LED fixtures in this specific retail application?

   c. What other lighting products did you consider? How did you differentiate between similar products on the market?

   d. What were the performance criteria in your selection of the specific product?
      i. Efficacy (Lumens per Watt)
      ii. Light distribution
      iii. Color rendering of products
      iv. Lamp field performance
      v. Lamp replacement labor costs
      vi. Other

   e. Did external *agencies* helped inform your selection process (DOE, MSSLC, CALiPER, ENERGY STAR, DLC, utility programs, etc.)? If so, how?

   f. What external *companies* helped inform your selection process (Lighting contractors, designers, sales representatives, etc.)? If so, how?

4. **Influence of utility incentive programs**
    a. How did the presence of a utility program affect your decision to move forward?

    b. On a scale of 1-5, 1 being not important at all, and 5 being very important, how did utility support in the following areas affect your decision to move forward?

| | | | | | |
|---|---|---|---|---|---|
| i. Incentive | 1 | 2 | 3 | 4 | 5 |
| ii. Project assistance | 1 | 2 | 3 | 4 | 5 |

    c. Are there any additional utility program services that would assist you in future decisions?

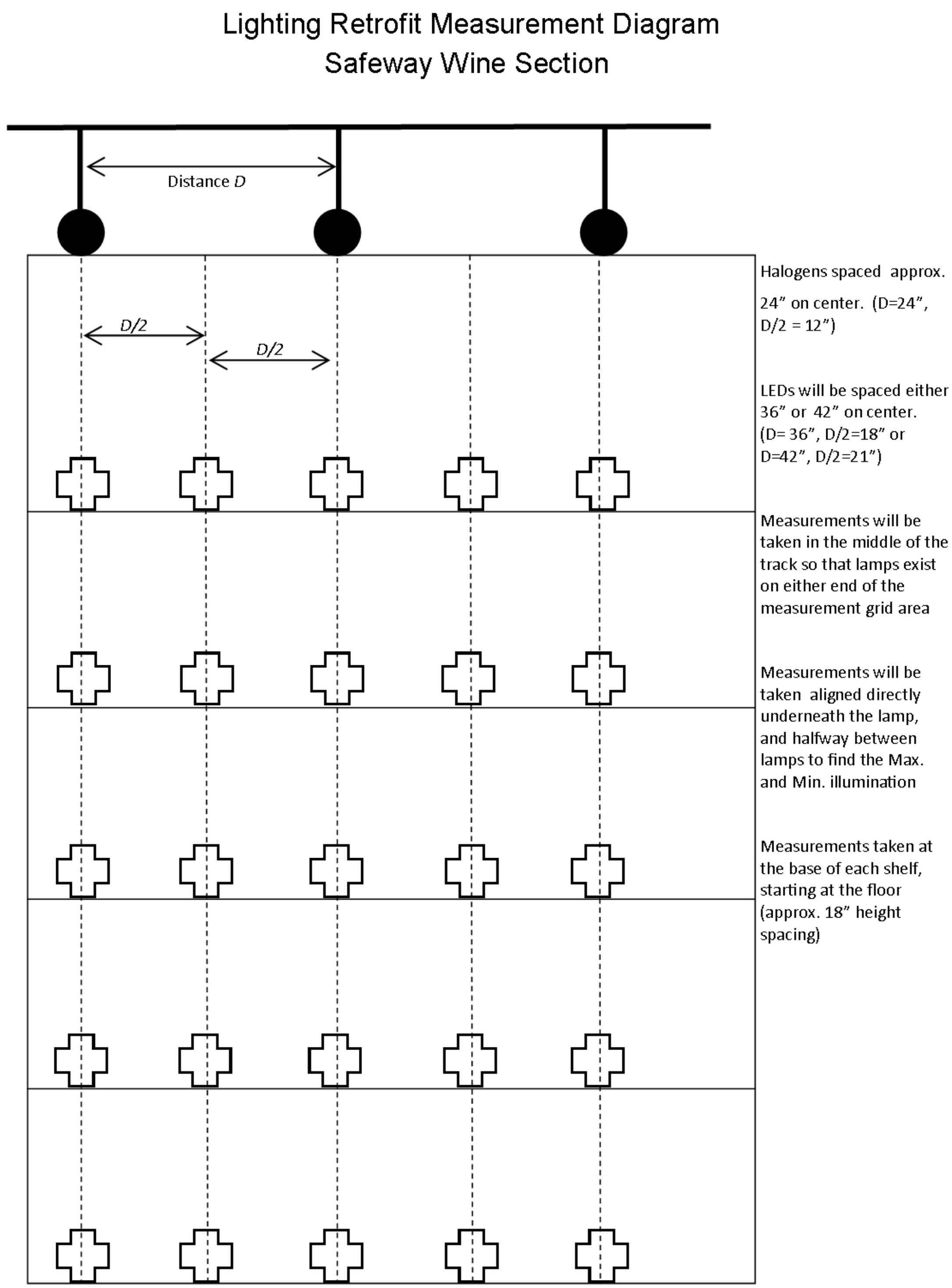
5. **Decision to scale to other stores**
    a. Describe the field-testing process you completed prior to your decision to scale.
    b. What were your criteria for approval to scale? Were they the same as the initial fixture selection?
    c. Once Safeway has approved the fixture and made the decision to scale, what are the next steps in this process?
    d. What is the timeline of this longer scaling process?
    e. Please rank the following in order of importance in your decision to scale:
        i. Product Enhancement
        ii. Energy Savings

6. **Demand Response and Dimming**
    a. Does your lighting control system allow fixture dimming? If so, is this feature used in the store? Where is it used?
    b. Would you consider using dimming capability on fixtures in the future?
    c. Are your lights controlled through an energy management system? Is this system able to accept automated demand response (DR) signals?

d. Would Safeway be willing to participate in an automated DR program for MR16 fixtures? Are there additional lighting sources you would consider implementing DR for?

7. **Store Employee or Customer Survey (To be given to the department managers)**
   a. Did you (employee/customer) notice the lighting replacement?
      i. Do you think it improves or worsens the retail atmosphere?
      ii. Overall, how satisfied are you with the new lighting atmosphere?
      iii. Would you recommend that Safeway adopt this in other stores?

# Appendix B: Lighting Measurement Diagram



# Appendix C: Additional Data

**White wine - Halogen**

| | Lamp | | Lamp | | Lamp |
|---|---|---|---|---|---|
| Shelf 4 (72") | 70.2 | 84.3 | 70.5 | 52.5 | 48.9 |
| Shelf 3 (57") | 53.0 | 43.3 | 38.3 | 32.8 | 37.5 |
| Shelf 2 (42") | 22.0 | 19.0 | 13.7 | 15.4 | 24.8 |
| Shelf 1 (27") | 11.9 | 10.7 | 9.3 | 8.5 | 13.6 |
| Floor (0.0") | 10.6 | 10.4 | 10.4 | 8.9 | 8.0 |

# Appendix D: Description of Scaled Field Placement for PG&E Emerging Technology Program

**Scaled Field Placements**

a. Description - These projects consist of placing a number of measures at customer sites as a key step to gain market traction and possibly gain market information. The measures will typically have already undergone an assessment or similar evaluation to reduce risk of failure. While the number of units in scaled field placements will vary widely, numbers typically larger than in an assessment of the technology are expected. A very simple example of a scaled field placement would be to give 50 office managers an LED task light. Monitoring activities on each scaled field placement will be determined as appropriate.

The following table highlights the distinctions between technology assessments, scaled field placements, and demonstration showcase.

| *Parameter* | **Technology Assessments** | **Scaled Field Placements** | **Demonstration Showcases** |
|---|---|---|---|
| *Purpose* | performance, cost data → EE programs | market traction | Visibility |
| *Theme* | evaluation | first-hand experience | Exposure |
| *Units installed* | one to a few (exceptionally, many) | a few to many | one (or entire floor/building/facility) |
| *Number or sites* | one to a few (exceptionally, many) | a few to many | One or more as strategically valuable |
| *Unique measures* | One | one | more than one measure up to whole systems (exceptionally, just one) |
| *Customer impact* | one or a few users | few to many users | large number of viewers |
| *Visibility* | very little | targeted | Public |
| *Duration* | as needed for data collection | life of measure | duration of public interest / impact |
| *Data collection* | Detailed | none to moderate | none to moderate |
| *Dissemination mechanism* | printed report & other media | first-hand experience and word of mouth | short-term exposure and word of mouth |

b. Rationale - Scaled field placements work under the premise that end-users or stakeholders with adoption influence (installers, builders, and procurement officers) will be positively influenced by first-hand experience utilizing a measure and that this first-hand experience will lead to future measure purchases/use. This method of

influence is fundamentally different from assessments that influence through information dissemination via a report or other results media.
Scaled field placements will be most effective when:
• The stakeholder gaining exposure has the potential to influence a large number of future purchases/uses. Example: Placing a high-efficiency air conditioning unit with several large HVAC contractors. "Potential to influence" is a broad term. Influence of the participant stakeholder could stem from purchase decision power, high frequency of interactions with other potential adopters, or status as a thought leader.

• First-hand experience is projected to be more influential for a measure than less costly dissemination mechanisms such as printed information or media. Technology complexity and concern regarding human factors are potential causes for first-hand experience to be more influential than printed media. Example: Placing energy efficient retail lighting at a WalMart, Target, and Home Depot store.

c. Barriers addressed – Scaled field placements address Information or Search Costs, Performance Uncertainties, Organizational Practice or Customs, as well as contributing to efforts by others to overcome Hidden Costs and Asymmetric Information and Opportunism.

For instance, scaled field placements reduce the time that large-scale decision makers and decision influencers must spend looking for and confirming the performance of EE measures – as first-hand experience eliminates these needs.

d. Expected outcomes – Scaled field placements will contribute to increased measure awareness, market knowledge and reduced performance uncertainties for ETP stakeholders and large scale customer decision makers and decision influencers. This will lead to changes in organizational practices and customs that may otherwise limit EE measure procurement and application.

Scaled field placements can also contribute to a market tipping point, in which an influential buyer or decision maker responsible for large volume purchase decides to specify the EE measure – thus creating a spike in market demand and exposure for many people who experience the measure once it is implemented. Over time, scaled field placements may support increasing use of measures by customers, aiding EE programs in achieving energy and demand savings targets, and meeting long term Strategic Plan and policy objectives.

# References

Amerlux (2012), *Hornet Product Specification Sheet*. http://www.amerlux.com/uploads/files/LIT-1061_HORNET_LED_0612.pdf

Arcadian Lighting (2012), *Transformer Info on Low-Voltage Lighting Systems*. http://www.arcadianlighting.com/transformer-guide.html

[DEER] Database for Energy Efficient Resources (2010), developed by the California Public Utilities Commission. Accessed 15 December 2012, http://www.deeresources.com/

[DOE] Department of Energy (2012a), *CALiPER Exploratory Study: Retail Replacement Lamps – 2011*. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_retail-replacement_2011.pdf

[DOE] Department of Energy (2012b), *Lighting Facts Product List*. Accessed 15 December 2012. http://lightingfacts.com/download/products/all

[DOE] Department of Energy (2012c), *Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps: Host Site: Intercontinental Hotel, San Francisco, CA* http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_intercontinental-hotel.pdf

[DOE] Department of Energy (2012d), *Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps: Host Site: Smithsonian American Art Museum, Washington, D.C.* http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_gateway_smithsonian.pdf

[DOE] Department of Energy (2008), *Performance of Halogen Incandescent MR16 Lamps and LED Replacements*. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/mr16_benchmark_11-08.pdf

[DLC] DesignLights Consortium (2012), *Qualified Products List.* http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php

Energy Solutions (2012), *Draft Analysis of Standards Proposal for Small Diameter Directional Lamps (Unpublished)*. Prepared on behalf of the California IOUs.

ENERGY STAR (2012), *ENERGY STAR Qualified Light Fixtures Product List*. Accessed 15 December 2012. http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LU

[ECEEE] European Council for Energy Efficient Economy (2011), *Evaluating the Potential of Halogen Technologies*. http://www.eceee.org/Eco_design/products/directional_lighting/halogen_technologies_report/eceee_report_halogen_technologies.

Fiberoptics Technology Inc. (2012), *Color Temperature.* http://www.fiberoptix.com/technical/light_source_lamp_characteristics.php

LEDs Magazine (2012a), "Low-Voltage LED Lamps Present Unique Driver Challenge." http://ledsmagazine.com/features/9/2/10.

LEDs Magazine (2012b), "Are MR16 LED lamps ready for the 50W-halogen switch?" http://ledsmagazine.com/features/9/6/8.

[RPI] Rensselaer Polytechnic Institute Lighting Research Center (2002), *Lighting Answers: MR16 Lamps*. http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/mr16/abstract.asp

Navigant (2011), *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications*. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/nichefinalreport_january2011.pdf

Navigant (2010), *International Directional Lamp Regulatory Review.* London: Department for the Environment, Food and Rural Affairs. http://efficient-products.defra.gov.uk/assets/Uploads/Defra-Report-Directional-Lamps-Task-1-v.10a.pdf

Osram Sylvania (2012), *50MR16/B/FL35 Product Specification Sheet*. http://ecom.mysylvania.com/sylvaniab2c/b2c/init.do?shop=GL-L0&Product=58321

Riker, C, T. Cook, and T. Pang (2008), *LED MR16 Lighting Demonstration: West Sacramento, CA.* Prepared on behalf of Pacific Gas and Electric Company. Application Assessment Report #0728. http://www.etcc-ca.com/reports/images/stories/ikea20final20report-dec2020081.pdf

[UL] Underwriters Laboratories (2012), *Photometric Indoor Test Report*. Allentown, PA:UL Verification Services.