Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Report #0722

LED Refrigerated Case Lighting
Costco, Northern California

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PREFACE

Customer Energy Efficiency Program

EMCOR Energy Services, under contract to Pacific Gas & Electric Company (PG&E), has conducted a study of an Emerging Technology Project at a host customer site, which is a merchandise wholesale retailer in Northern California. The purpose of this project is to assist PG&E with the evaluation of an emerging technology in the application of refrigerated case lighting, as discussed herein.

This report is the result of an emerging technology demonstration project performed as a part of the Customer Energy Efficiency (CEE) Program administered by PG&E. This program is part of PG&E's commitment to meeting new demand growth through energy efficiency by providing technical assistance directly to customers.

EMCOR Energy Services (EES) of San Francisco, California, prepared this document for PG&E as a contractor under the CEE Program. The PG&E Emerging Technologies Program Lead is Maria Easnor. The PG&E Project Manager for this project is Mary Matteson Bryan, P.E.

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ACKNOWLEDGMENTS

EMCOR Energy Services gratefully acknowledges the assistance of Costco and PG&E.

1. EXECUTIVE SUMMARY

EES evaluated an emerging technology application that potentially provides lighting energy efficiency improvements. This technology was tested at a merchandise wholesale retail facility in Northern California. In this demonstration project, light emitting diode (LED) source illumination was installed to replace T8 fluorescent lighting in two freezer (low temperature) cases and one refrigerated (medium temperature) case. The project consisted of replacing (216) 5-foot F40T8 fluorescent lamps and associated solid-state ballasts with (216) customized LED bars at existing locations.

Power draw was measured before, during, and after project installation. This information was used to quantify energy savings resulting from installation of the new technology. In addition, quantitative measurements were made on the light output and quality associated with the base case and test case lighting.

Power measurements indicated that this project reduced the electric demand of the case lighting systems by approximately 53%. Although a reduction in illuminance of 42% was calculated with the replacement system, luminance values only declined by 17% on average. The consistency of the lighting was found to be more uniform with the LED system than with the fluorescent system. The results indicate that the test case LED lighting system is more efficacious overall than the base case fluorescent system. Additional demand savings occurred because of the reduction in refrigeration requirements associated with reduced heat gain from the lighting system to the refrigerated space. See Table 1.1 for a summary of the performance of the two lighting systems.

Photometric measurements were also performed. For reference, Section 6.3 contains a brief discussion of lighting and photometric terms. As shown in Table 1.2, the LED system provides more consistency in luminance values than does the fluorescent system. This observation is supported by the ratios of maximum to minimum luminance calculated from the measured data. Features related to color temperature were also measured. Section 6 provides an expanded discussion of these findings.

The annual lighting energy savings of 21,272 kWh for the demonstration project were calculated based on a continuous lighting demand reduction of 5.1 kW for the measured hours of operation (80 hours per week), extrapolated to calculate annual savings. Refrigeration system savings of 10,011 kWh/year were calculated based on a continuous reduction of average compressor demand. Total project savings are calculated to be 31,283 kWh/yr. The costs of electricity and electrical demand were computed based on the time-based occurrence of project savings using PG&E's E-19S rate, typical for warehouse retail stores; the monetary value of the annual energy savings was computed to be approximately $4,161 per year.

Replacement of fluorescent systems with new LED systems will result in avoided maintenance costs over the life of the new LED system. This is because the LED system has a longer effective useful life than the fluorescent system, resulting in fewer equipment replacements and lower maintenance costs over its life. Based on average life characteristics of the current and proposed equipment, more than two cycles of fluorescent lamp replacement will be avoided during the expected life of the LED system. During that period, it is also expected that a small percentage of ballasts for the fluorescent fixtures will fail annually; the percentage of actual failures will likely be higher or lower depending on the age of the ballasts. The avoided costs due to maintenance are calculated for this case study to average approximately $1,223 annually over the life cycle of the LED source.

Table 1.1: Lighting System Performance

Case	Average Power	Average Luminance	Average Illuminance
T8 Fluorescent - Base Case	9.6 kW	163 cd/m^2	78 fc
LED Light Bar - Test Case	4.5 kW	136 cd/m^2	45 fc
Test Case as a percent of Base Case	47%	83%	58%
Percent Reduction	53%	17%	42%

Table 1.2: Lighting Quality Attributes

Lighting Quality Attribute	Fluorescent System	LED System
Max-min luminance ratio computed based on 8 measurement points, Butter Case	3.6 to 1 (3.6:1)	1.9 to 1 (1.9:1)
Max-min luminance ratio computed based on 8 measurement points, Egg Case	1.7 to 1 (1.7:1)	1.5 to 1 (1.5:1)
Color Rendering Index (CRI)	62 – 85[a]	(not quantified)
Correlated Color Temperature (CCT)	3500K to 4100K (typical) 3580K (measured)	3423K (measured)

a) The CRI for an older, cool white system, which is typical for refrigeration case lighting, is 62; a typical CRI for newer fluorescent technologies, the base case at this site, is 85.

Given current market conditions, the installed cost of the project is estimated to be approximately $52,434, resulting in a simple payback period of 12.6 years based on energy savings alone. The vendor of the product tested in this study, LED Power, foresees a reduction in product cost of approximately 15% as the market for this application matures. Labor cost reductions associated with implementing this technology are already being realized as companies, including LED Power, are developing specialized in-house labor capabilities for case lighting retrofit work.

Based on a mature market, the estimated cost for implementation is approximately $41,000, with a simple payback period of 10.0 years based on energy savings alone. Including the impact of avoided maintenance costs, the project payback period improves to 9.7 years for the current case, and is projected to be 7.7 years in mature market conditions. See Table 1.3 for a summary of project savings and estimated economics.

The base-case lighting and refrigeration systems in this study are relatively modern and efficient. The savings estimates are thus conservative, relative to older, less efficient base-case equipment present in other facilities.

The effective useful life of the product is conservatively estimated to be 50,000 hours. The usage of the lighting systems is estimated to be approximately 4,171 hours per year. The application has a positive life cycle cost based on current market conditions and energy savings alone.

A report was previously completed for an LED refrigerated case lighting retrofit at a Northern California grocery store under the Emerging Technologies program. Section 2.2 provides a comparison of LED performance results between this study and the previous study. As a result of technological improvements, the efficacy of the LED systems increased from 26.7 lumens per watt in the prior study to 32.8 lumens per watt in this study.

LED lighting is a rapidly advancing technology. It is anticipated that on-going improvements to the LED technology, power supplies, and installation methods will lead to continuing price reductions and higher energy savings. Also, as economies of scale are realized and competition among manufacturers increases, prices are expected to decline. These forces are expected to result in continued improvement in the economics of LED technologies. In the near term, utility incentive programs can reduce the first cost to the customer and potentially accelerate market adoption of this promising energy efficient technology.

Table 1.3: Lighting System Savings and Economics

Project Component	Energy Savings (kWh/yr)	Electrical Demand Reduction (kW)	Annual Cost Savings			Cost and Payback (Current Conditions)			Cost and Payback (Mature Market)		
			Energy ($/yr)	Maint. ($/yr)	Total ($/yr)	Cost ($)	Payback, Energy Effects Only (yrs)	Payback, Total Effects (yrs)	Cost ($)	Payback, Energy Effects Only (yrs)	Payback, Total Effects (yrs)
Lighting	21,272	5.1	inc.								
Refrigeration	10,011	2.4	inc.								
Total	31,283	7.5	$4,161	$1,223	$5,384	$52,434	12.6	9.7	$41,442	10.0	7.7

2. PROJECT BACKGROUND

2.1 LED Technology Overview

LED sources are well known as efficient lighting technologies. Developed in the 1960's, early limitations in use were due to color restrictions imposed by the primary usable elements: initially red only. LEDs developed in the 1980's incorporated new materials that allowed flexibility in the design of LED output color, and engendered commercial applications such as exit signs, indicators, and traffic signals. The 1990s saw the advent of blue and white LED sources, offering a much broader range of applications than previously available. Advances in the technology's materials science have also extended LED expected life, brightness, and efficacy.

2.2 Application Assessment Studies

One application of LED sources that has been tested in the marketplace is the use of pre-wired LED assemblies to provide illumination for refrigerated grocery cases. The Lighting Research Center at Rensselaer Polytechnic Institute (RPI) published a study on this application, "Refrigerated Display Case Lighting with LEDs".[1] This 2002 laboratory study illustrates a strong customer preference for product displayed in a prototype LED-illuminated case as compared with product displayed in a case illuminated by fluorescent sources. In the study, the fluorescent source provided more light than the LED system, at a lower input power. Although the LED system was less efficacious than the fluorescent system, the LED source provided more uniform lighting. The study concluded the improved uniformity was the main basis for the customer preference.

The Lighting Research Center at RPI completed a follow-on study that evaluated LED lighting performance and shopper's lighting preferences for grocery store freezer cases, "Energy-Efficient Lighting Alternative for Commercial Refrigeration".[2] "Surveys showed that shoppers preferred the LED freezer over the fluorescent freezer, even when the LED lighting was dimmed to a light level 25% lower than that of the fluorescent freezer".

A report was previously completed for an LED refrigerated case lighting retrofit at a Northern California grocery store under the PG&E Emerging Technologies Program. Comparisons between the two studies are illustrative of changing technologies and variance in field conditions. Table 2.1 shows a comparison of the two refrigerated case lighting studies.

The 2006-2007 study at the Northern California grocery store (prior study) resulted in a projected simple payback period of 6.7 years while the 2007-2008 study (this study) resulted in a longer simple payback period as noted in Section 1 of this report. The base case for the prior study was a high output fluorescent lighting system, resulting in significantly higher power draw and illuminance levels on average than were measured in this study.

The LED systems used in the prior study provided less light output per watt consumed (lumens/watt) than the systems used in this more recent study. The efficacy (lumens/watt) of the next generation LED systems from LED Power has improved by 23% in the 12 months between the prior study and this study. The replacement LED system evaluated in this study afforded a greater percentage reduction in power than the replacement system evaluated in the prior study.

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[1] Raghavan, Ramesh and Narendran, Nadarajah, 2002
[2] Narendran, Brons, Taylor, 2006

Table 2.1: Comparison with Previous LED Refrigerated Case Lighting Study

Study	Dates of Study	Base Case Lamp Type	Test Case LED System Efficacy (lumen/W)[3]	Base Case Average Measured Power per Door (W)	Test Case Average Measured Power per Door W)	Reduction in Power (%)	Base Case Average Illuminance (fc)	Test Case Average Illuminance (fc)	Reduction Illuminance (%)	Annual Lighting System Operation	Simple Payback (yrs)
Northern California Grocery Store[4]	2006-2007	5' 58W T8 [high output]	26.7	75W	43W	43%	186	129	31%	6,205	6.7
COSTCO, Concord California	2007-2008	5' 40W T8 [standard]	32.8	59W	28W	53%	78	45	42%	4,171	12.6

[3] Based on measured power and rated lumen output for the prior study; measured power and ITL testing lumen output for the current study
[4] Theobald, Marc A., "LED Supermarket Case Lighting Grocery Store, Northern California" Application Assessment Report #0608, " PG&E and EMCOR Energy Services. January 2007

Although the LED systems evaluated in the more recent study are more efficient than those evaluated in the prior study, the viable load reduction (31 W per case door) was slightly less than the load reduction of 32 W per door afforded by the much more brightly illuminated base case conditions associated with the prior study. Differences in load reduction potential, system operating hours, utility rate structure, and cost of implementation contributed to a longer simple payback period for the project associated with this study as compared with that shown for the prior study.

2.3 Current Technical and Market Status

Virtually all refrigerated cases are illuminated by fluorescent sources, which are reasonably efficient and reliable. Fluorescent sources are optimized to operate at “normal” indoor ambient temperatures of 60 to 80˚ F. Cold temperature adversely impacts the light output of fluorescent systems by as much as 60% from peak values for some lamp types at sub-freezing temperatures.[5]

LED assemblies for use in refrigerated cases are currently available in the marketplace, however. Several systems, including General Electric’s “Lumination”, and NuaLight’s “Vantium”, for example, are designed specifically for use in the low temperature, retail display case market. Both the GE product and the European Vantium can be controlled with dimming devices to optimize power and light to the application. Anthony International, the world’s largest manufacturer of commercial glass refrigerator and freezer doors, provides its OptiMax LED lighting system as a standard option for many cold case door configurations. The sales representative for Anthony International indicated that 11 to 15% of doors currently sold contain LED sources, and the trend for this technology is accelerating.

The products used in this demonstration were LED light bars manufactured by LED Power for use in refrigerated cases.

A competing emerging technology for refrigerated case lighting is the use of fiber-optic sources; with a remote illuminator, no heat is present within the conditioned space. Evaluation of this technology is outside the scope of this study.

[5] Illuminating Engineering Handbook, 9th Edition, Chapter 6, Figures 6-41 & 6-44

3. PROJECT OBJECTIVES

PG&E's Emerging Technologies Program seeks to accelerate the market penetration of energy-efficient technologies, applications, and tools that are not widely adopted in California. Projects such as this serve to measure, verify, analyze, and document the potential energy savings and demand reduction of specific technologies and applications in different market segments.

One project objective was to compare quantitatively the brightness and light quality (color) of LED and fluorescent freezer case lighting systems in a field application. This study sought to determine the applicability of the emerging technology to the refrigerated case environment.

Quantification of potential energy savings was a second goal. This study incorporated on-site measurement to determine the level of energy savings available from replacing the standard refrigerator case lighting source (fluorescent) with the emerging technology (LED). The study also sought to identify further available savings due to reduced refrigeration load requirements.

A third goal was to solicit customer feedback regarding the project implementation and outcome. A customer survey was designed and provided to PG&E for obtaining feedback. A copy of the survey is provided in Appendix D of this report.

4. EXPERIMENTAL DESIGN AND PROCEDURE

4.1 Background

Prior to this study, PG&E had identified LED sources as an emerging technology application for refrigeration case lighting, conceived of a "test case", and identified a host customer, a Northern California merchandise wholesale retail facility, to participate in the test.

PG&E accordingly drafted a scope of work outlining the basic steps required for a field evaluation of this technology, and this was incorporated into the requirements for this study. EMCOR Energy Services drafted a test protocol to be used in planning for and conducting the field-testing of the pre- and post- case lighting systems. The test protocol is included as Appendix B to this report.

One of the requirements that preceded this study was for existing fluorescent lamps to be replaced with new fluorescent lamps and ensuring they "burned in" for at least 100 hours to stabilize the baseline condition. The purpose for this adjustment to the baseline condition was so that the light output of both existing and replacement light sources could be compared at the same point of depreciation, in this case as "new".

The following key dates and milestones outline the major procedures and schedule for the project:

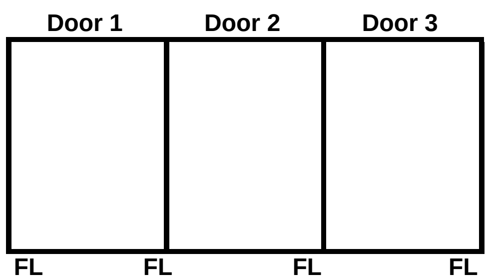
December 04, 2007	Complete of photometric testing and power measurement protocols.
December 05, 2007	Store had new fluorescent lamps installed in cases included in study.
December 06, 2007	Install recording power meter logger on case lighting circuit. Spot metering of individual loads and circuits for baseline.
December 11, 2007	Perform baseline photometric testing.
December 20, 2007	Disconnect recording power meter logger from case lighting circuit.
January 10, 2008	Complete the replacement of fluorescent sources with LED sources in test cases.
January 14, 2008	Install recording power meter logger on case lighting circuit for post-case.
February 1, 2008	Perform post-case photometric testing.
February 1, 2008	Disconnect recording power meter logger from case lighting circuit.
February, 19, 2008	Finalize customer survey.
February/March 2008	Evaluate and analyze data.

4.2 Project Scope and Definition

PG&E worked with the host customer to identify a facility and corresponding low and medium temperature cases for testing. The test area consists of 162 illuminated doors located in three large refrigerated cases. These cases are served by a system of refrigeration compressors, which are located in a remote indoor service space near the main electrical distribution.

The test area base-case lighting is provided by F40T8 5-foot fluorescent lamps powered by solid-state ballasts. Lamps typically are situated vertically along the interior of each doorframe; effectively there are four lamps per each three-door standard door set. Ballasts are remote from the case in an insulated housing to prevent unnecessary heat gain to the refrigerated compartment. A total of 216 fluorescent lamps and associated ballasts provide illumination and power for the base-case lighting in the test area. The figure below illustrates the base case:

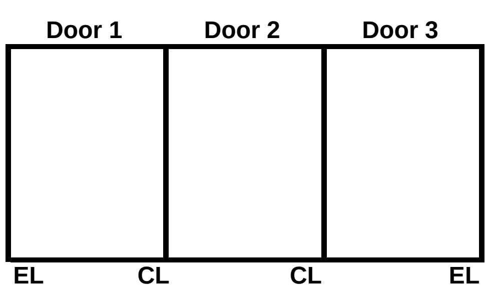
Figure 4.1: Base Case Light Fixture Configuration



FL = 5' F40T8 fluorescent lamp, rated @ 40 W

The test-case lighting is provided by LED Power, inc. The units are light bars that are designed for door case illumination of merchandise in the refrigerated case environment. The installation consists of two different LED bar configurations, both types equipped with refractive optical lenses. End Lamp (EL) strips contain 114 LEDs (rated 15 W) and are installed at the sides of three-door sections, facing inward. Center Lamp (CL) strips contain 228 LEDs, (rated 30 W). LEDs are positioned to face in alternating directions so that light is spread from the center mullion in two directions to provide even illumination across the door. LED strips of both types are powered by driver units, which were installed remote from the case so as to minimize unnecessary heat gain to the conditioned area. The figure below illustrates the position of the two types of LED assemblies as configured in a typical three-door case.

Figure 4.2: Test Case Light Fixture Configuration



EL = "End Lamp" unit w/114 LEDs, rated 15 W
CL = "Center Lamp" unit 2/228 LEDs, rated 30 W

Baseline and test-case system data sheets are included in Appendix A, “Product Data Sheets”. Photographs of the baseline and test-case systems are shown in Figures 4.3 and 4.4, respectively.

Figure 4.3: Baseline Fluorescent Lighting System

Figure 4.4: Test-case LED Lighting System

4.3 Photometric Testing

EES devised a testing protocol for the purpose of characterizing the lighting system performance in reach-in freezer cases. The photometric testing protocol for this study is provided in Appendix B. The protocol requires that tests be conducted in the freezer case when in steady-state at its normal operating temperature, with the freezer case closed. The following key testing components were included:

- Measurement of vertical luminance at various locations on the merchandise,
- Measurement of vertical illuminance on product shelf,
- Determination of light uniformity,
- Determination of correlated color temperature.

Following development and acceptance of the photometric testing protocol, EES performed measurements to characterize the baseline (fluorescent source) and test-case (LED source) conditions. Measurements were performed with case doors open and closed. The results from the doors being open were used for the analysis to minimize the effects of reflection caused by the general (overhead) lighting system on the results.

EES further analyzed and interpreted the data and prepared a characterization of the lighting systems, which is included in Section 6.3. The analysis and reports are also included in Appendix B of this report.

4.4 Power Measurement Testing

The EES project team developed a power measurement testing protocol for the purpose of determining the power requirements for and the energy use by the baseline and test-case lighting systems. EES pre-programmed the data logger to record at 5-minute intervals.

EES employed a Dent Elite-Pro data logger electric demand (kW) meter, which was installed and removed per the project schedule noted above. EES identified the circuits in the breaker panel that were associated with the case lighting. EES identified that each breaker on the low temperature cases served nine doors and each breaker in the medium temperature case served twelve doors.

EES selected the following circuits for testing: Breaker #17 (low temperature), Breaker #30 (low temperature), and Breaker #53 (medium temperature).

Generally, refrigerated case lighting at this facility is controlled by a lighting control system and was noted to operate according to the following schedule (Mondays – Fridays 10:00 a.m. – 10:00 p.m., Saturdays 10:00 a.m. – 9:00 p.m., and Sundays 10:00 a.m. – 7:00 p.m.). It should be noted that Breaker #51 (medium temperature) was not controlled by the lighting control system and the associated fixtures operated continuously.

EES installed three current transducers (one per circuit) and the data logger. The data logger recorded volts, amps, power factor, and kW at 5-minute intervals for all three circuits, one per channel.

Summary power data measurements are provided in Appendix C-2.

5. FACILITY INFORMATION

The host facility is a merchandise wholesale retailer located in Northern California. PG&E provides electrical service. Retail outlets of this type in PG&E's service territory normally qualify for an E-19S time-of-use electricity rate because they have a power demand between 500 and 1,000 kW. The actual utility information for this site is held confidentially by the owner and was not used in the development of this report.

The rate schedule E-19 is a time-of-use (TOU) tariff, meaning electricity is provided at different rates depending on when it is used. Based on E-19 rate schedule information provided on PG&E's website, the average electricity cost during the occurrence of project savings was calculated to be $0.1330/kWh, including demand charges. Please refer to Appendix C-2 for rate information.

6. PROJECT RESULTS

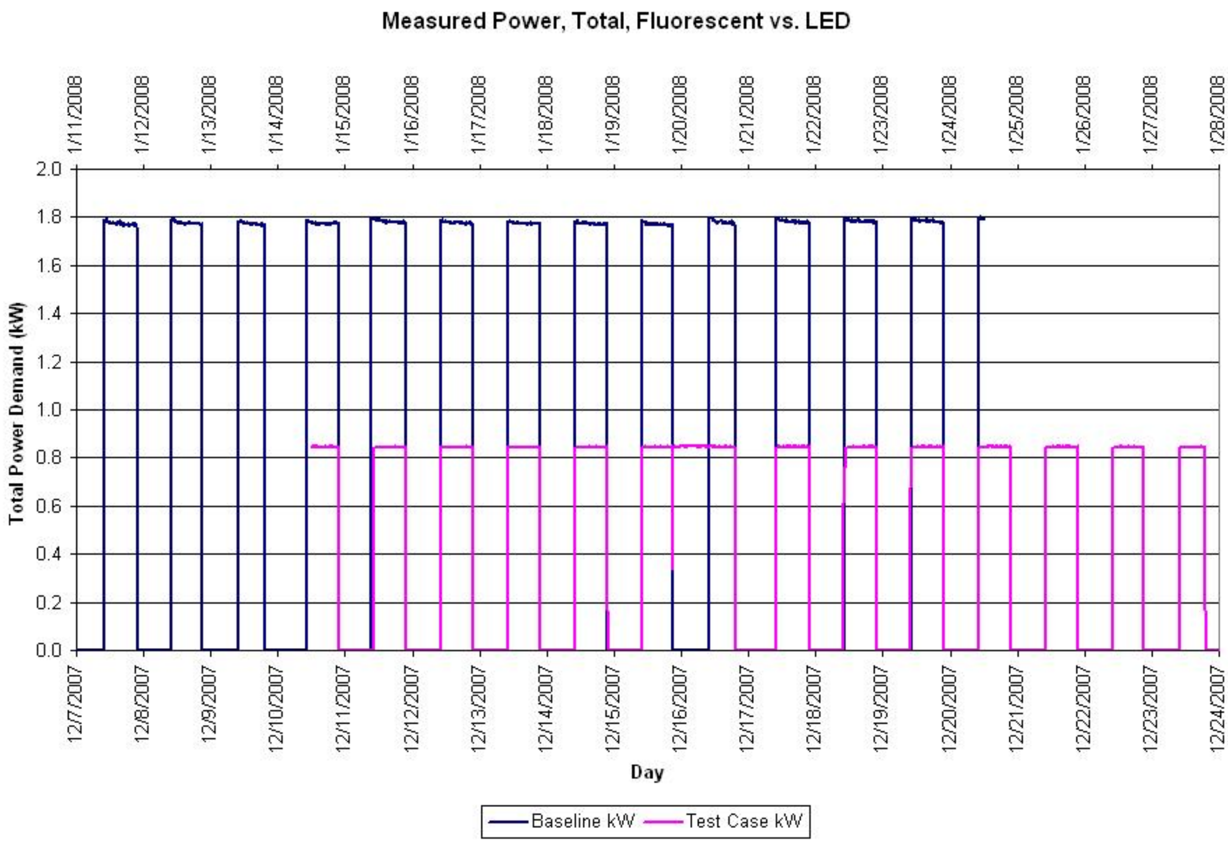
6.1 Electrical Energy and Demand Savings

The calculated savings are based on replacing 216 fluorescent lamps and associated ballasts with 216 LED bars in two low temperature cases and one medium temperature case. The temperature indicated in the low temperature cases was -15°C while the medium temperature case indicated a temperature of 5°C.

The average power data used in the calculations represent three entire metered circuits consisting solely of the lighting sources that serve these cases.

Figure 6.1 illustrates the lighting load reduction associated with the three measured circuits.

Figure 6.1:



Energy Savings

Replacement of the base-case lighting system with test-case lighting resulted in a savings of 21,272 kWh per year in lighting savings, plus an estimated 10,011 kWh per year in refrigeration savings. The total project savings is calculated to be 31,283 kWh annually. See Appendix C-2 for calculations.

The host customer uses timer controls to schedule the case lighting systems to operate during store hours, for approximately 12 hours per day Mondays through Fridays, 11 hours per day on Saturdays, and 9 hours per day on Sundays.

The recorded data support that the lighting operates continuously during the regularly scheduled intervals. During the installation of the LED light bars, the contractor noted that lighting associated with Breaker #51 was operating uncontrolled. The contractor moved the lighting from Breaker #51 to Breaker #53, which is controlled by the lighting control system. Since EES was monitoring the lighting already on Breaker #53, the overall load on Breaker #53 showed a marked increase for the post case because the lighting from Breaker #51 was added. Adjustments were made to the post case data to remove the effects of the additional load from the results.

The data for the periods when the lighting was on during the base-case monitoring period were averaged for each channel on a per-lamp basis (44.4 W) and multiplied by the total number of lamps (216), to arrive at the base load of 9.6 kW.

Similarly, the data for the periods when the lighting was on during the test-case monitoring period was averaged for each channel based on the total power draw of the LED lighting for a three-door case, which is calculated to be 83.3 W. This unit value was multiplied by the total number of three-door cases (54), to arrive at the test case load of 4.5 kW.

Annual lighting energy use for both cases was calculated based on extrapolation of the operating hours as derived from the data. The annual energy savings were calculated as the difference between the two conditions, extrapolated to a one-year period.

Both the fluorescent and LED systems generate heat at the ballast (driver), and at the light source itself. In this case, heat generated by the ballast (driver) does not increase the refrigeration load because it is outside the case. Refrigeration system savings were calculated based on the difference between the heat loads the two light sources generated within the conditioned area. This calculation used an assumed coefficient of performance (COP) of 1.4 for the low temperature refrigeration cases and a COP of 2.5 for the medium temperature refrigeration case. This is a conservative assumption of compressor efficiency derived from industry-accepted performance literature. See calculations in Appendix C-2.

Demand Savings

The calculated demand reduction for the lighting system replacement was 5.1 kW, based on the average connected loads derived from measured data as described above. The load reduction on the refrigeration system was calculated to be 2.4 kW, on average. The calculated refrigeration system load reduction is about 47% of the lighting load reduction, which is in line with GE's reported results of 45%.[6]

[6] "GELcore Improves LED Lighting for Refrigerated Displays", LEDs Magazine June 7, 2006, www.ledsmagazine.com/press/12567

The lighting systems operate continuously during the scheduled-on period, including during all of the utility peak electricity rate period. The refrigeration systems are enabled to operate continuously, and were observed to cycle in short intervals, i.e., less than 15 minutes, and the reported demand reduction takes this into account. The demand savings for this project are coincident because they reduce the electric load during the utility peak demand period.

The base-case lighting and refrigeration systems in this study are relatively modern and efficient. The savings estimates are thus conservative, relative to older, less efficient base-case equipment present in other facilities.

The limitations in energy and demand savings applicability are minimal, provided the lighting performance of the LED system meets the user's requirements.

6.2 Maintenance Savings

Replacement of fluorescent systems with new LED systems will typically result in avoided maintenance costs over the life of the new LED system. This is because the LED system has a longer effective useful life than the fluorescent, resulting in fewer equipment replacements and lower maintenance costs over its life. Based on average life characteristics of the current and proposed equipment, more than two cycles of fluorescent lamp replacement will be avoided during the expected life of the LED system. During that period, it is also expected that a small percentage of ballasts for the fluorescent system will fail annually; the percentage of actual failures will likely be higher or lower depending on the age of the ballasts. The overall avoided maintenance costs during the expected life of the LED system are calculated in Appendix C.

The avoided costs due to maintenance are calculated to average approximately $1,223 annually over the life cycle of the LED source. These savings are included in the project economics as shown in Table 1.3.

6.3 Lighting Performance

Lighting performance was measured and assessed in terms of four main attributes: luminance, illuminance, color rendering index, and color temperature. The Lighting Design Lab[7] provides an online glossary of lighting terms; key terms are described below as a background to the test parameters.

luminance: The luminous intensity of a surface in a given direction per unit area of that surface as viewed from that direction; often incorrectly referred to as "brightness."

illuminance: The density of incident luminous flux on a surface; illuminance is the standard metric for light levels, and is measured in lux (lx) or footcandles (fc).

color rendering index (CRI): A measurement of the amount of color shift that objects undergo when lighted by a light source as compared with the color of those same objects when seen under a reference light source of comparable color temperature. CRI values generally range from 0 to 100.

color temperature (K): The absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source; measured in Kelvin.

Detailed information is provided in Appendix B, including luminance maps, graphs, and photos.

[7] http://lightingdesignlab.com/library/glossary.htm; permission for reproduction of glossary granted by Diana Grant, Lighting Design Lab Project Manager for a previous PG&E ET Assessment, 10/25/06

Luminance

Luminance is measured in candela per square meter, cd/m^2. Figure 6.2 compares the luminous intensity of the two sources, based on a comparison of fluorescent and LED sources in two cases, one displaying eggs and one displaying butter. The luminance maps are provided for review in Appendix B-2. The fluorescent sources generally result in more luminance than do the LED, as illustrated.

Figures 6.3 and 6.4 compare the maximum and minimum luminance readings measured for the butter and eggs cases, respectively, at the same doors as measured for Figure 6.2. LED provides more consistency in luminance values from door to door.

The overall max-to-min. luminance ratio for each door was computed based on eight measurement points. For the butter case, the overall luminance ratio was 3.6 to 1 (3.6:1) for the fluorescent source, and 1.9 to 1 (1.9:1) for the LED. For the egg case, the luminance ratio was 1.7 to 1 (1.7:1) for the fluorescent source and 1.5 to 1 (1.5:1) for the LED.

The max-to-min. luminance ratio for the egg display is not as pronounced as for the butter display. This may be attributed to a greater uniformity in product packaging and placement in the egg display, which results in more consistent readings for both sources.

It should be noted that baseline luminance readings were recorded at a display of frozen edamame (soybeans). The display was chosen because the packaging was visually consistent. Due to re-merchandizing activities outside the control of this project, the display was no longer in place when the post-case measurement was performed. As a result, there are no direct comparisons of luminance available for the freezer case associated with this study.

Figure 6.2: Average Luminance Results: Butter & Eggs

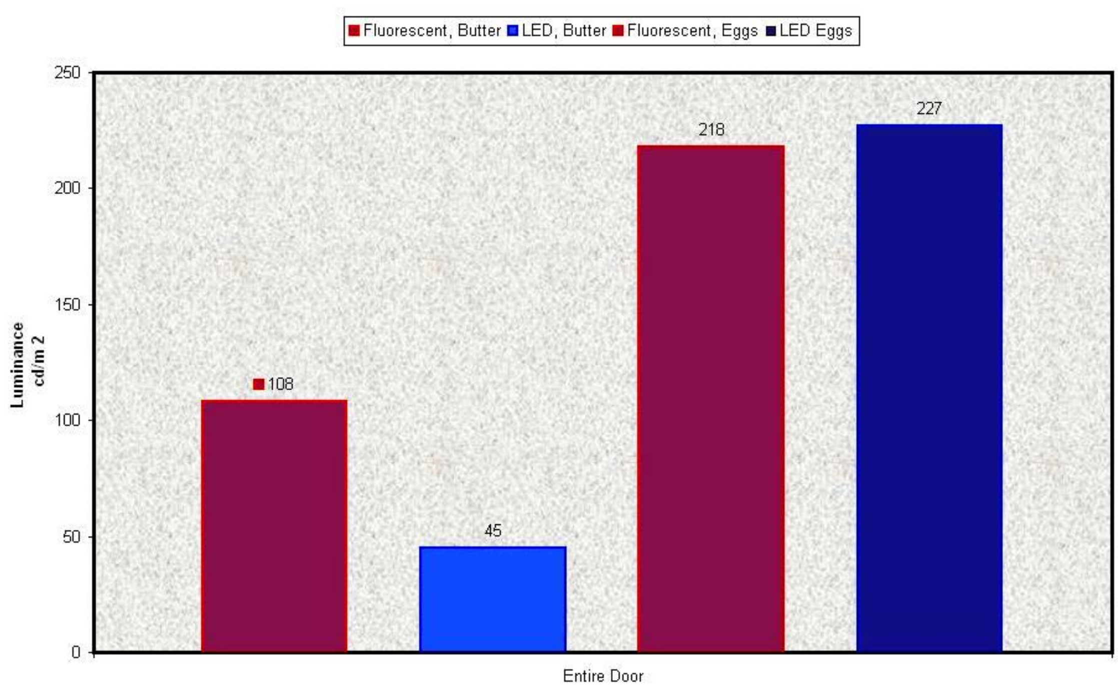


Figure 6.3: Max to Min Luminances - Butter

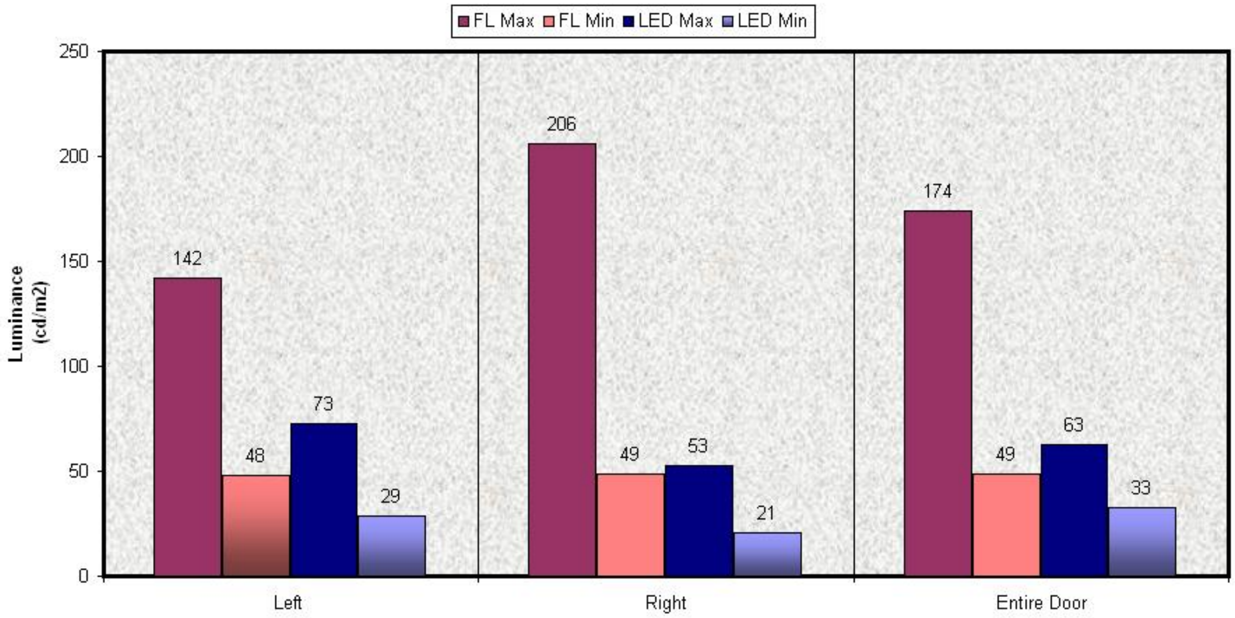
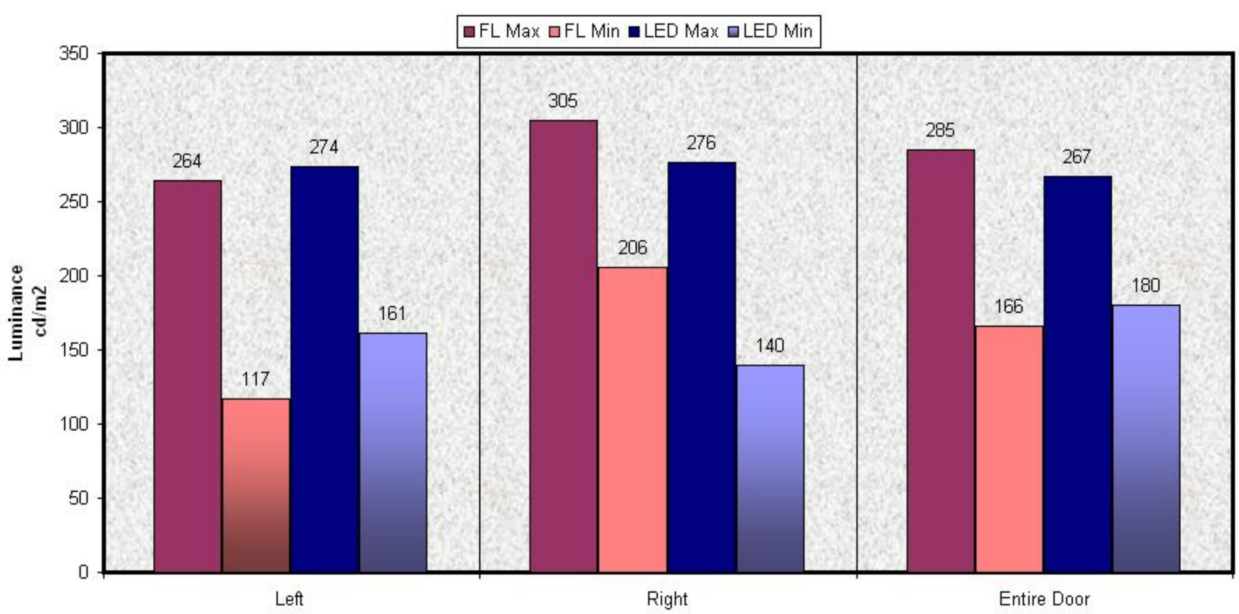


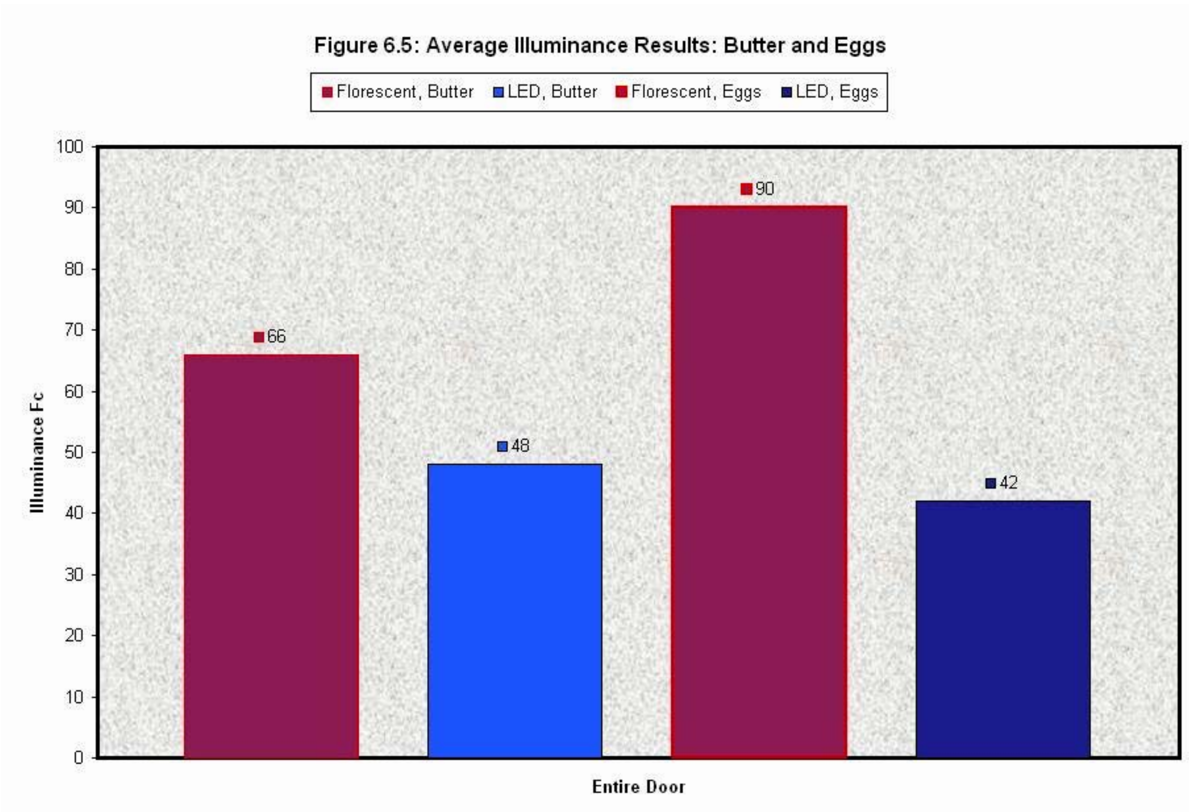
Figure 6.4: Max to Min Luminances - Eggs



Illuminance

EMCOR recorded illuminance values (light levels) for this study, and they are reported in footcandles. The composite results are shown for two displays, butter and eggs, as provided in Figure 6.5. For reasons stated previously, no comparisons are drawn with regards to illuminance values on product located in the freezer case.

This chart below shows a similar pattern in terms of illuminance distribution for the fluorescent and LED sources, and indicates that the LED system provides less illuminance than the base case.



Correlated Color Temperature (CCT)

A light source with a higher CCT appears as a cooler color than that of a lower CCT. The color of the LED source tested and used in the demonstration is specified as “Warm White,” with a rated color temperature of 3500K. The color temperature for the LED was measured in the field with the results of 3423K.

The fluorescent source, Sylvania FO40/841/XP/ECO, has a rated color temperature of 4100K.

The variance in color temperature between the two types of sources is not significant when considering a wholesale transfer from one type of light system to the other for freezer cases. Use of the two technologies side by side, however, would produce a noticeable difference in color appearance.

Laboratory Testing

Pacific Northwest National Laboratory, representing the US Department of Energy (DOE) in the SSL Gateway Demonstration, submitted sample LED luminaires to Independent Testing Laboratories (ITL) for photometric testing. The tested fixtures, manufactured by LED Power, were similar to the fixtures installed for this project but not identical: the 60” light bar tested for efficacy contained 276 LEDs while the installed light bar contained 228 LEDs. LED Power provided one-foot and five-foot LED light bar samples to DOE for testing. Complete test results are provided in ITL test reports 60172, 60197, and 60198, shown in Appendix B-3.

ITL 60172 reports the distribution photometry and input electrical parameters for a nominal 60” light bar and driver similar to the system used at the Costco installation. The sample was too big to fit in the integrating sphere test chamber for testing of color attributes; so smaller (1’ length) LED lightbar units were subjected to color testing as reported in ITL 60197 and ITL 60198. The LED lightbar tested in ITL 60197 contained 48 LEDs while the lightbar tested in ITL 60198 contained 60.

ITL 60172 results indicated that the full-sized light bar consumed 36.1 W while providing a total of 1,105 lumens. This calculates to an efficacy of approximately 31 lumens per watt. Based on results from ITL 60197 and 60198, the efficacy for the one-foot LED lightbars ranged from 25 to 30 lumens per watt. The units tested consistently in color rendering, recording a color rendering index value of 79 to 80 CRI.

The efficacy results provided by the laboratory tests (about 30 lumens per watt) are lower than the system efficacy as calculated based on a ratio of the manufacturer’s stated lumen output of the LEDs and the input power as measured in the field (45.6 lumens per watt). An average of 4 lumens per LED is calculated from the results of ITL 60172, as opposed to 6 lumens per LED as reported by the manufacturer.

DOE staff reports that it is not uncommon for independent photometric test results of LED lighting systems to be at variance from manufacturers’ claims for LED systems.

6.4 Incremental Cost for Materials and Installation

For factory-installed LED lighting systems, the incremental cost for this measure is the cost premium to the end user for this option. For retrofit of existing cases, the incremental cost of the project is the actual installed cost.

PG&E's discussions with LED Power indicate that the current equipment cost for the light bars is about $266/door for this installation, including the power supply component. LED Power expects the prices to drop to approximately $226 per door as the market matures.

The Contractor estimate of current labor cost for this measure is $58 per door. As an estimate of mature market labor costs, LED Power expects to offer a service to install LED light bars to end-use customers. The cost of this service is projected to range from $30 to $35 per door for large scale applications, and represents a step in market maturity from previous practices of hiring electricians unfamiliar with this type of retrofit work.

The project cost derived from the indicated assumptions was used to calculate a project simple payback period under two scenarios: 1) current market conditions and 2) mature market conditions. See Table 1.3 for a summary of project economics. Additional information is provided in Appendix C-2.

6.5 Useful Life

The California Public Utilities Commission 2004-05 Database for Energy Efficient Resources (DEER), available on the Internet, provides effective useful life (EUL) values for many energy-saving technologies. DEER does not provide an EUL value for LED refrigeration case lighting because the technology is so new. The EUL for an LED exit sign or retrofit kit is estimated to be 16 years (over 140,000 hours), according to DEER. The core technology, LED sources and driver, are similar for both the established application (exit sign lighting) and the emerging technology (refrigeration case lighting).

LED Power provided an expected life of 50,000 hours for the LED low-temperature case lighting, which is much less than the DEER estimate of 16 years for LED exit sign technology. It is well documented that LED life is extended in a low-temperature environment;[8] therefore, the EUL of 50,000 hours assumed for this application is probably conservative.

6.6 Customer Feedback

EES developed a customer survey form to be used to gather data about the customer's satisfaction with the tested lighting system. Following completion of the work, customer feedback was solicited from store personnel via telephone. The store manager responded to the questionnaire. The manager reported his general level of satisfaction with the replacement lighting system to rank as "8" of a possible "10", with "10" being the highest score. He indicated that it was inconclusive whether the replacement lighting system created less visual interest or more visual interest than the previous lighting system, and that he thought both systems provided about the same amount of light.

Attempts to reach other store personnel to obtain feedback regarding this project were unsuccessful. A written copy of the survey results is provided in Appendix D.

[8] "LED Life for General Lighting" ASSIST, Vol., 1, No. 1, February 2005, Lighting Research Center

7. DISCUSSION

Site Coordination

The demonstration project was well coordinated between the host customer, the utility, and several outside consultants and contractors. No significant technical, customer, consultant, or contractor issues were encountered.

System Performance vs. Expectations

A review of manufacturers' literature and comparison of stated light output (lumens) vs. power requirements (watts) for both technologies suggests that the fluorescent system has a higher rated efficacy (i.e., more lumens/W). As discussed in Section 2.3, however, the cold temperature adversely impacts the light output of fluorescent systems by as much as 60% from peak values for some lamp types at sub-freezing temperatures. Conversely, LED performance is known to increase as LED internal temperatures are decreased. Refrigerated case environments operate at lower ambient temperatures than laboratory test conditions, which are used to assess LED performance. Due to properties of heat transfer, changes in LED internal temperatures correlate with changes in ambient temperature. As a result, LEDs operate cooler and thus more efficiently than in accordance with rated performance characteristics when operated in a cold environment, such as a refrigerated case.

Also, as shown in Figures 6.3 and 6.4, the photometric results indicate that the LED sources provide more consistency in luminance values. This results in light being delivered more consistently to the task.

These two factors, a cold environment and consistent luminance, result in LED sources performing better in a real-world application than would be suggested by comparing sources on the basis of product performance specification alone.

Measure Feasibility and Market Potential

The measure is technically feasible and cost-effective at current market conditions, with a projected simple payback period of 9.7 years (including maintenance savings) and an effective useful life of 50,000 hours.

The RPI study cited above states that "supermarkets spend nearly half their annual electric cost on refrigeration" and, "Studies have shown that lighting accounts for about 15% of the total energy consumed by commercial refrigerators".[9] This demonstration project achieves a 53% reduction in lighting energy usage, plus additional refrigeration savings. It should be noted, however, that this 53% reduction in lighting energy use corresponds to a 42% reduction in illuminance values. The reduction in total illuminance may be mitigated based on system performance issues as discussed above.

As mentioned in Section 2.3, factory sales of LED-illuminated refrigerated case doors are steadily growing, representing 11-15% of Anthony International Door's present volume of new case door sales. A significant market for door lighting retrofit exists.

[9] Raghavan, Ramesh and Narendran, Nadarajah, "Refrigerated Display Case Lighting with LEDs" page 1, 2002.

Given the extent of the grocery industry, the potential utility impact for this type of measure is extensive.

Future Technology Improvements

LED lighting is a rapidly advancing technology. It is anticipated that on-going improvements to the LED technology, power supplies, and installation methods will lead to continuing price reductions and increased energy savings. For example, the optical system used in this installation was more developed than that installed in a previous study performed for PG&E.[10] Also, vendors have introduced dimming LED systems to enable users to tailor light levels in accordance with specific field requirements. Finally, manufacturers have reported improvements in power supplies for use with LED systems. This combination of forces is expected to result in continued improvement in the economics of LED technologies.

[10] Theobald, Marc A., Northern California LED Supermarket Case Lighting "Application Assessment Report #0608." PG&E and EMCOR Energy Services. January 2007

8. CONCLUSIONS

An active wholesale retail store provides a challenging testing environment in that the laboratory is also a place of business, thus any changes in operations or appearance are scrutinized.

The results of the customer survey indicate that the demonstration project was well-received by the host customer, suggesting that one of the major barriers to implementation, user satisfaction, is surmountable for the application.

The other major traditional barrier to implementation is cost-effectiveness. The data support a significant savings opportunity for this type of application. The cost of implementation at current market conditions is in the range of the total savings available over the product's life, however.

Also, it is important to note that the cost-effectiveness of this technology in this type of application will vary according to actual site conditions. These include actual base case lighting wattage, system operating hours, refrigeration system characteristics, climate zone, and utility rate structure.

The cost-effectiveness barrier is expected to be overcome with maturing market conditions. Various incentive programs could help bring the price down to a cost-effective level for consumers even sooner.

PG&E uses this and other Emerging Technologies assessments to support development of potential incentives for emerging energy efficient solutions. Because the performance and quality of the LED fixtures are critical to the long-term delivery of energy savings, it is important that incentive programs include quality control mechanisms. Incentive programs should include performance standards for qualifying products that include minimum criteria for warranty, efficacy, light distribution, and other important criteria.

9. RECOMMENDATIONS FOR FUTURE WORK

As reported in Section 6.5, the estimate of useful life used in this study is thought to be conservative. Given the effect of temperature on LED performance, it is recommended that a follow-on study be conducted to assess the effective useful life for LED low-temperature case retrofits.

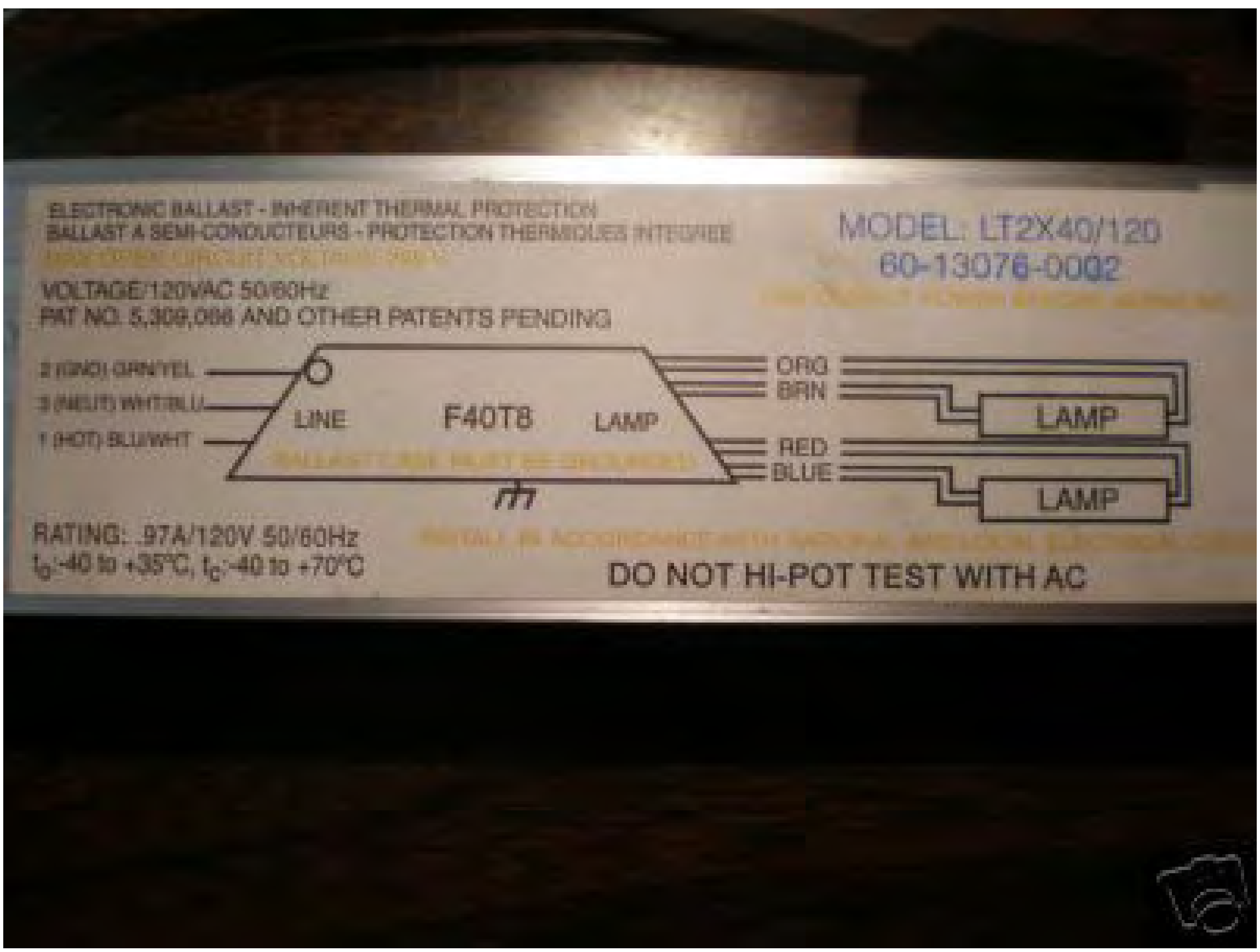
It is recommended that utilities work with outside vendors and internal marketing and outreach personnel to communicate the value of this technology to customers who may benefit from it, primarily the retail grocery market.

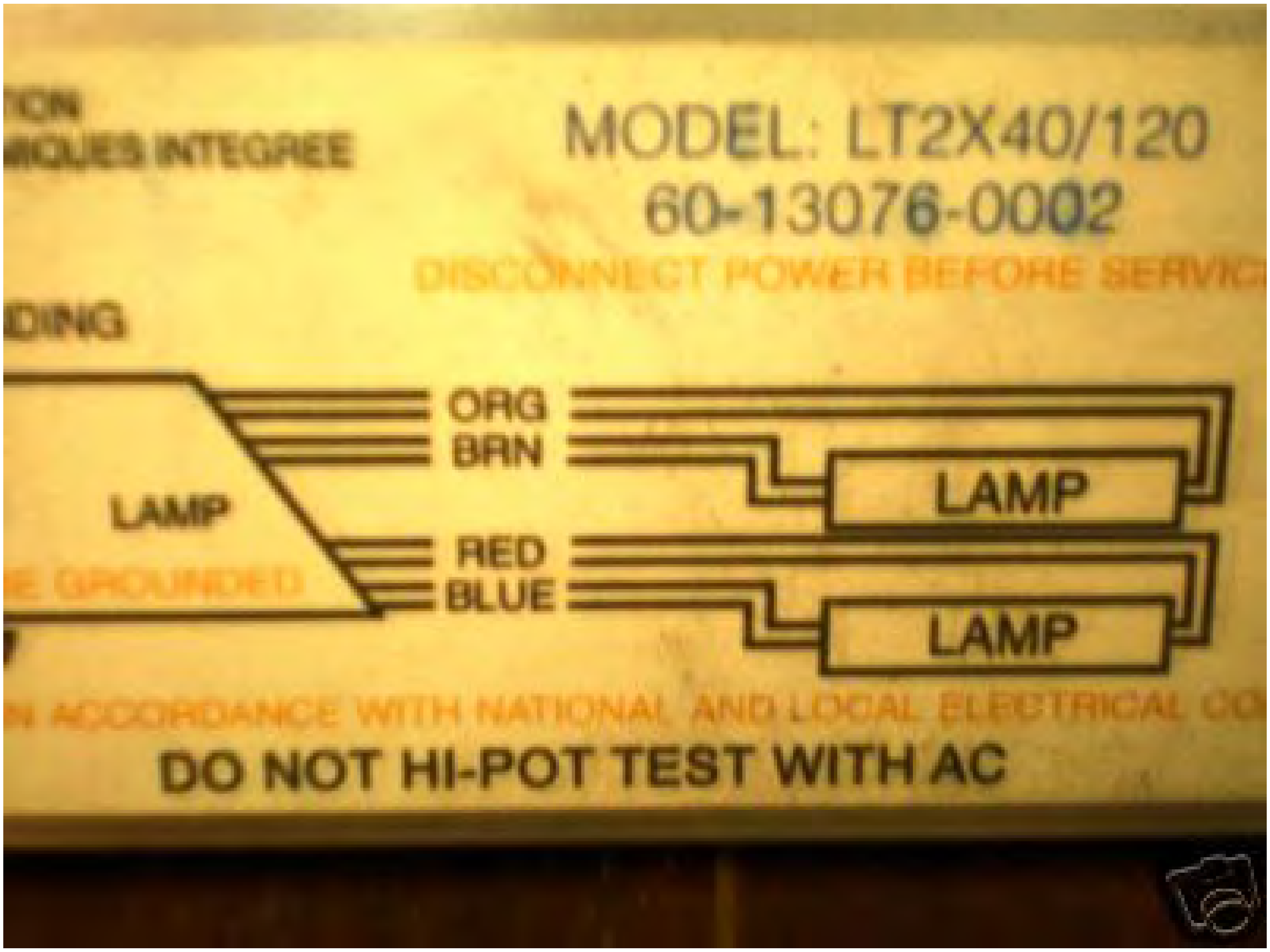
APPENDICES

Appendix A
Product Data Sheets

Appendix A-1
Base Case System


LINE
F40T8
LAMP
LAMP
LAMP
DO NOT HI-POT TEST WITH AC


ELECTRONIC BALLAST - INHERENT THERMAL PROTECTION
BALLAST A SEMI-CONDUCTEURS - PROTECTION THERMIQUES INTEGREE
VOLTAGE/120VAC 50/60Hz
PAT NO. 5,309,066 AND OTHER PATENTS PENDING
MODEL: LT2X40/120
60-13076-0002
2 (GND) GRN/YEL
3 (NEUT) WHT/BLU
1 (HOT) BLU/WHT
LINE
F40T8
LAMP
ORG
BRN
RED
BLUE
LAMP
LAMP
RATING: .97A/120V 50/60Hz
t_a:-40 to +35°C, t_c:-40 to +70°C
DO NOT HI-POT TEST WITH AC


MODEL: LT2X40/120
60-13076-0002
DISCONNECT POWER BEFORE
ORG
BRN
LAMP
LAMP
RED
BLUE
LAMP
GROUNDED
ACCORDANCE WITH NATIONAL AND LOCAL ELECTRICAL
DO NOT HI-POT TEST WITH AC


HIGH POWER FACTOR
LOW HARMONICS. MAX 10%
EMI: MEETS FCC CLASS A
SOUND RATING: A
CLASS: P
TYPE: 1 OUTDOOR
RAPID START - TYPE CC
NO PCB'S
FOR REFRIGERATION ONLY
MFG IN USA
LTX 1085
UL
C UL
LISTED

Return to search | Print Page

Product Number: 21916

Order Abbreviation: FO40/841/XP/ECO

General Description: 40W, 60" MOL, T8 OCTRON XP Extended Performance fluorescent lamp, 4100K color temperature rare earth phosphor, 85 CRI, suitable for IS or RS operation, ECOLOGIC

Product Information	
Abbrev. With Packaging Info.	FO40841XPECO 30/CS 1/SKU
Actual Length (in)	59.61
Actual Length (mm)	1514.1
Average Rated Life (hr)	24000
Base	Medium Bipin
Bulb	T8
Color Rendering Index (CRI)	85
Color Temperature/CCT (K)	4100
Diameter (in)	1.10
Diameter (mm)	27.9
Family Brand Name	OCTRON® 800 XP®, ECOLOGIC®
Industry Standards	ANSI C78.81 - 2001
Initial Lumens at 25C	3750
Mean Lumens at 25C	3560
Nominal Length (in)	60
Nominal Wattage (W)	40.00

Additional Product Information

Product Documents, Graphs, and Images

Compatible Ballast

Packaging Information

ECOLOGIC™

Footnotes

- Approximate initial lumens after 100 hours operation.

- The life ratings of fluorescent lamps are based on 3 hr. burning cycles under specified conditions and with ballast meeting ANSI specifications. If burning cycle is increased, there will be a corresponding increase in the average hours life.
- Life rating of OCTRON XP lamps operated on instant start electronic ballasts is 18,000 hours based on the industry standard life test cycle of 3 hours per start.
- Minimum starting temperature is a function of the ballast; consult the ballast manufacturer.
- OCTRON lamps should be operated only with magnetic rapid start ballasts designed to operate 265 mA, T-8 lamps or high frequency (electronic) ballasts that are either instant start, or rapid start, or programmed rapid start specifically designed to operate T8 lamps. OCTRON lamps may be operated on instant start ballasts with ballast factors ranging from a minimum of 0.71 to a maximum of 1.20 at the nominal ballast input voltage. When OCTRON lamps are operated in the instant start mode, the two wires or two contacts of each socket should be connected to each other. They should then be connected to the appropriate ballast lead wire using National Electric Code techniques.
- SYLVANIA ECOLOGIC fluorescent lamps are designed to pass the Federal Toxic Characteristic Leaching Procedure (TCLP) criteria for classification as non-hazardous waste in most states. TCLP test results are available upon request. Lamp disposal regulations may vary, check your local & state regulations. For more information, please visit www.lamprecycle.org
- The lamp lumen maintenance factor used to determine the mean lumen value was 95%. This is the lamp lumen maintenance factor at 8,000 hours, 40% of 20,000 hours. It was used to allow comparison to standard OCTRON(R) lamps with an average rated life of 20,000 hours. The lamp lumen maintenance factor at 40% of the 24,000 hour average rated life of this lamp, 9600 hours, would be 94%.*

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- Compact Fluorescent Bulbs
- European Base Bulbs
- Food Service Bulbs
- Full Spectrum and SAD
- Germicidal Lamps
- Halogen & Krypton Bulbs
- HBO & XBO Short Arc
- Incandescent Bulbs
- Mercury Bulbs
- Metal Halide
- Par Reflector Bulbs
- Photocells & Sensors
- Satco Products
- Xenon Gas Bulbs

Atlanta Light Bulbs Inc. catalog page, **Item: ANTHONY 60-13079-0002**. Please click ORDER below to confirm and add your item to your cart.

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ANTHONY 60-13079-0002 $149.95

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X
x
x
X

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Appendix A-2
Test Case System

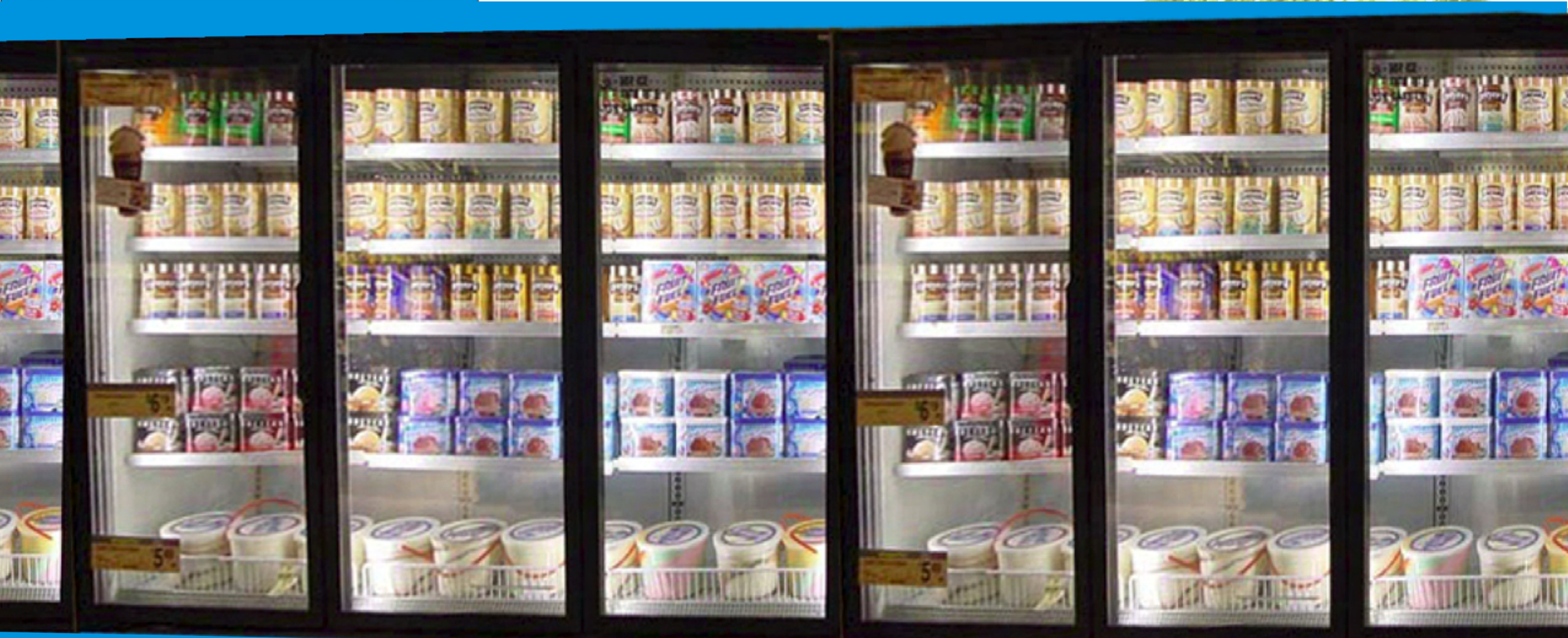
LED POWER

Better Product Visibility

Less Energy • Less Heat

Less Maintenance

Less Energy!
Clear Light!
MORE SALES!



LED Refrigerator & Freezer-Case Lighting

Install in 10 Minutes!

Dimmable!

Demand Response!

Various Color Temps!

Green Power LED Lights are the ideal replacement for energy hogging fluorescent tubes in refrigerated and freezer display cases.

Low Current • Low Wattage • Low Heat

- Dramatically improve product visibility with uniform light distribution.
- Reduce maintenance costs while lowering your electric bill!

www.LEDPower.com
T: 949.679.0031

Increase your sales
Decrease your Electric bill!

Low power consumption achieved without sacrificing luminance

LED technology excels in cold environments, unlike fluorescents. LEDs also require less energy and provide a more pleasing light than fluorescents.

Better product visibility equals more sales.
Less energy and heat means a smaller electric bill.
The results – more profit for you!

Standard Lengths 48-60” for New and Retrofit Applications

These technologically advanced light bars feature patented linear refractive optics for superior light efficiency. All illumination standards can be met with minimum power consumption. Ordinary LED systems utilize reflectors behind their LEDs which are expensive and an inefficient technology. Fluorescent tubes radiate light in all directions while LEDs project and collimate light in only one direction. Refractive optics will always be superior to reflective systems and are computer optimized for refrigerator and freezer applications.

LED Refrigerator & Freezer-Case Lighting

Save up to **50% on wattage consumption** compared to fluorescents! Additionally stores will save even more because our LED technology generates substantially less heat than fluorescent fixtures and even quite a bit less than competing LED systems! This means your compressor will not have to work as hard to cool the case. More added benefits are dimming and no warm up time for full brightness.

LED Lights just look better than fluorescents and that means **more sales**! With the LED Light Bar you get even light distribution across the case plus it maintains a more pleasing color temperature. Maintenance costs are greatly reduced for years to come.

Its time for a **Green** solution that's better for the environment, makes your product look better, sell better and does it all at lower cost!

LED Power, Inc

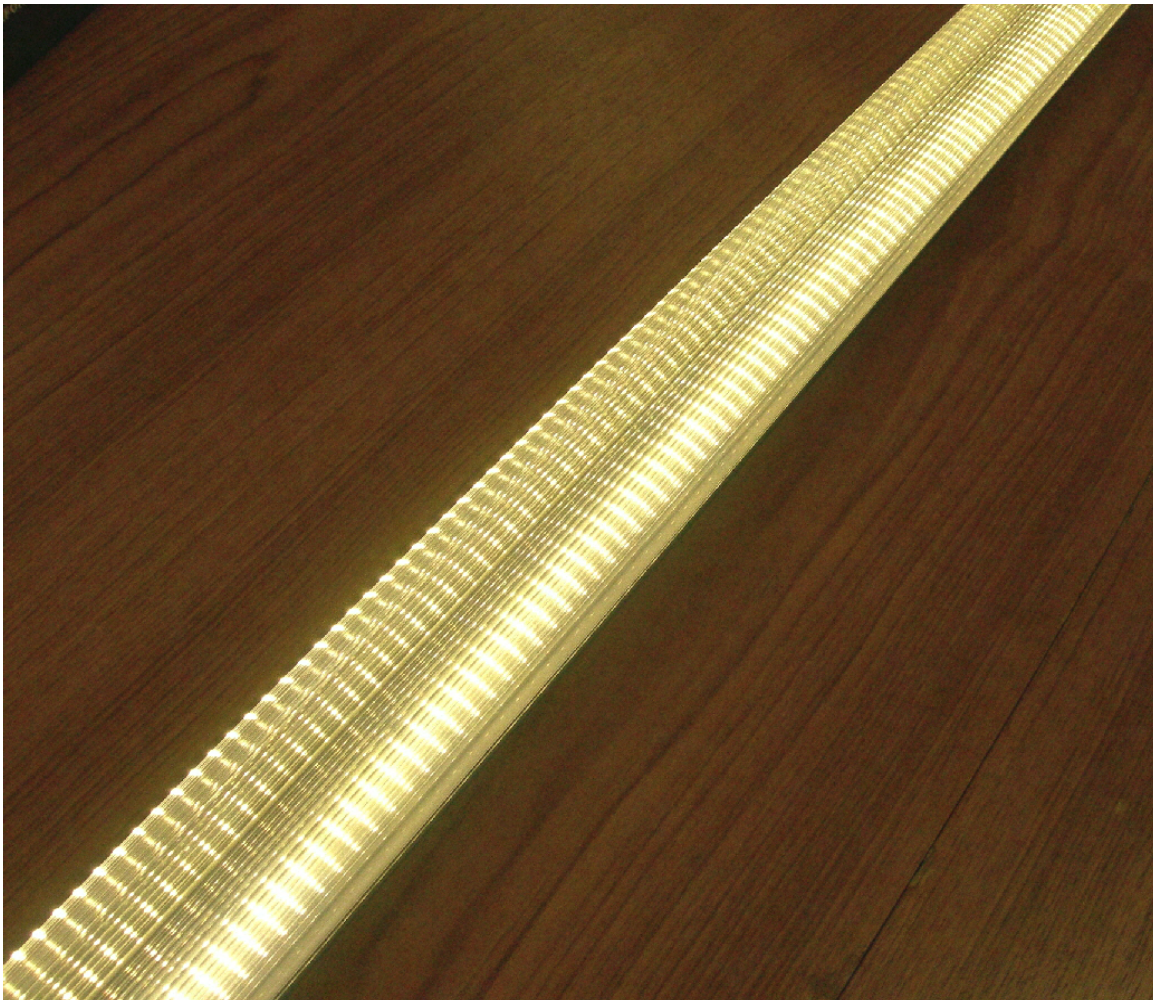
17875 Sky Park North, Suite E
Irvine, CA 92614

949 679 0031 PHONE • 949 679 0037 FAX
info@ledpower.com • www.ledpower.com

LED Refrigerator & Freezer Case Lighting

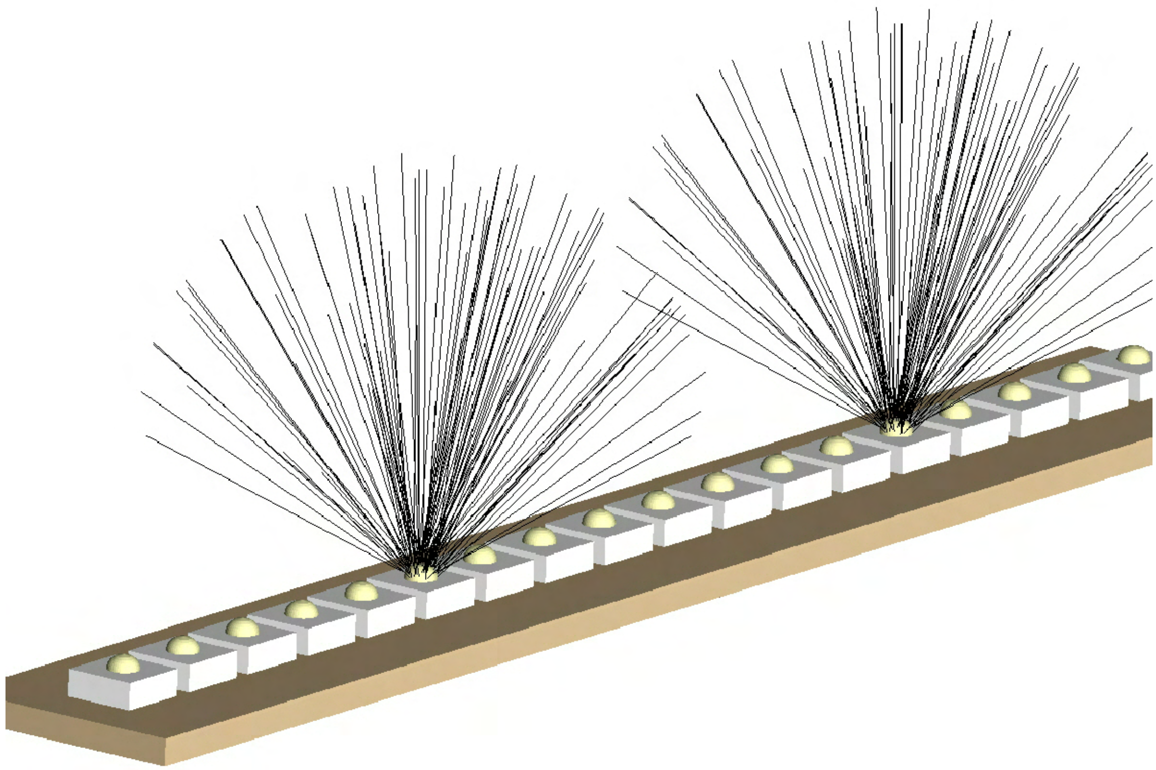
Green Power LED Lights

Energy Conserving - Rebate Eligible - Low Maintenance - Long Life

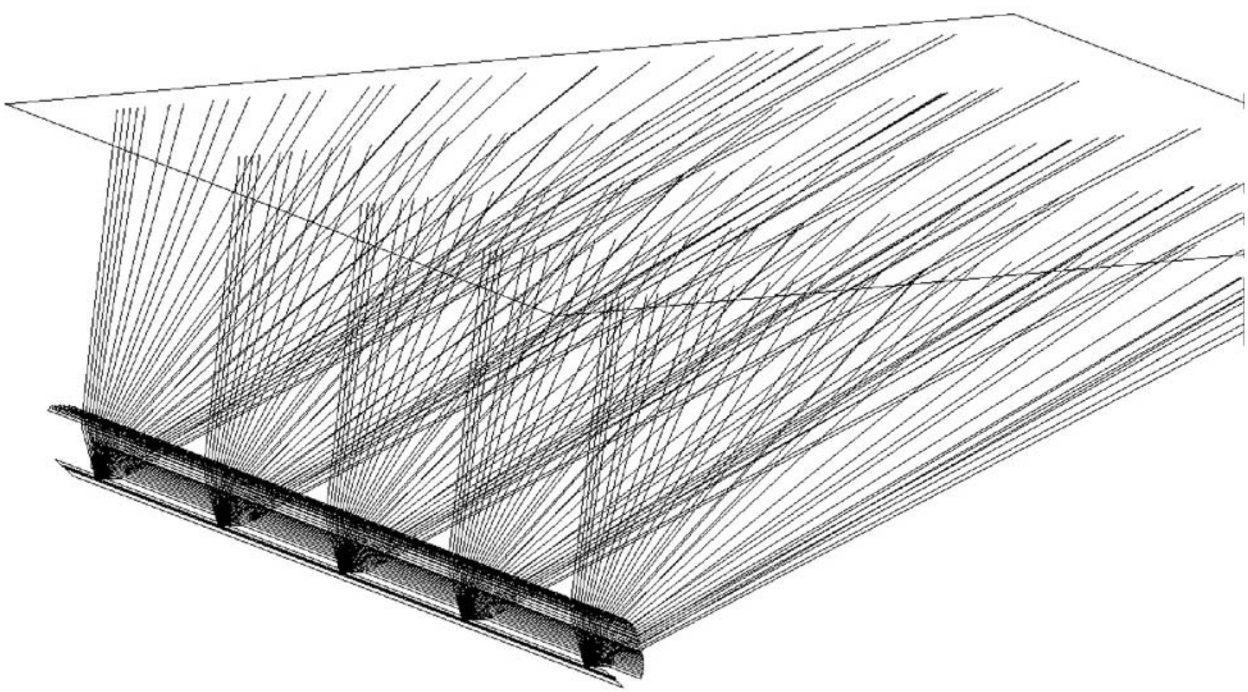


Standard Lengths from 48” - 60” for New and Retrofit

These advanced light-bars utilize unique linear-refractive optics for superior light efficiency, enabling all illumination standards to be met with minimum power consumption. Ordinary light-bars utilize reflectors behind their LEDs, but this expensive and inefficient technology is a left-over from incandescent lights of decades past. Incandescent and fluorescent lights radiate in all directions, but LEDs into only a hemisphere or less. Therefore refractive optics will always be superior to reflective systems. Moreover, these Advanced Linear Optics are computer-optimized for this application, achieving uniform illumination of quite nearby shelves.

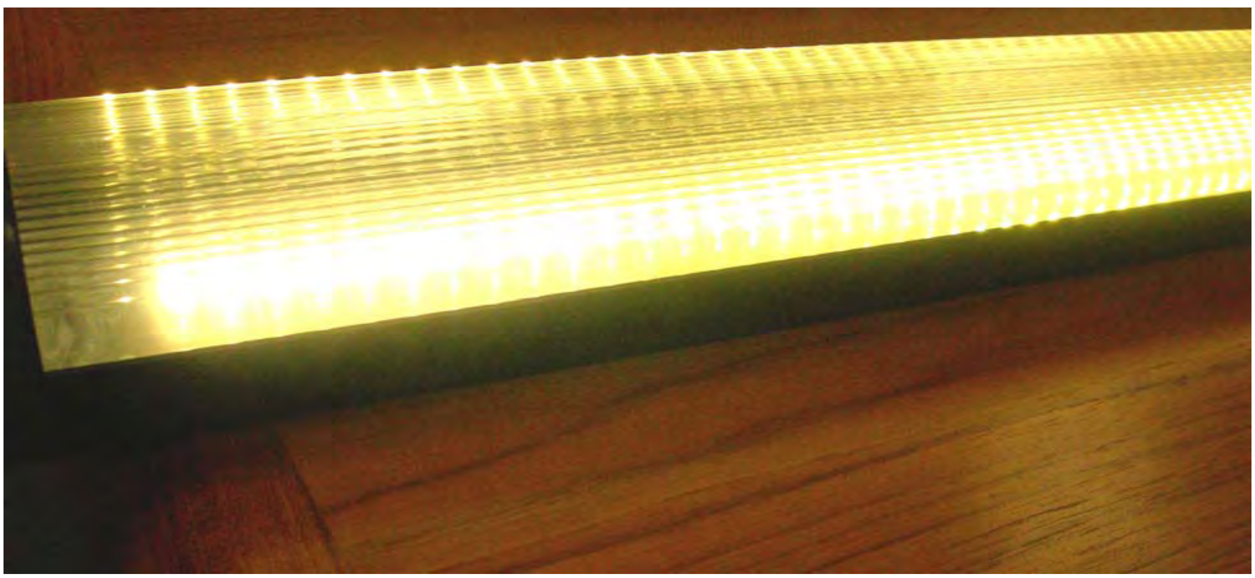


Computer modeling of LED light engine with representative rays shown from two of them.



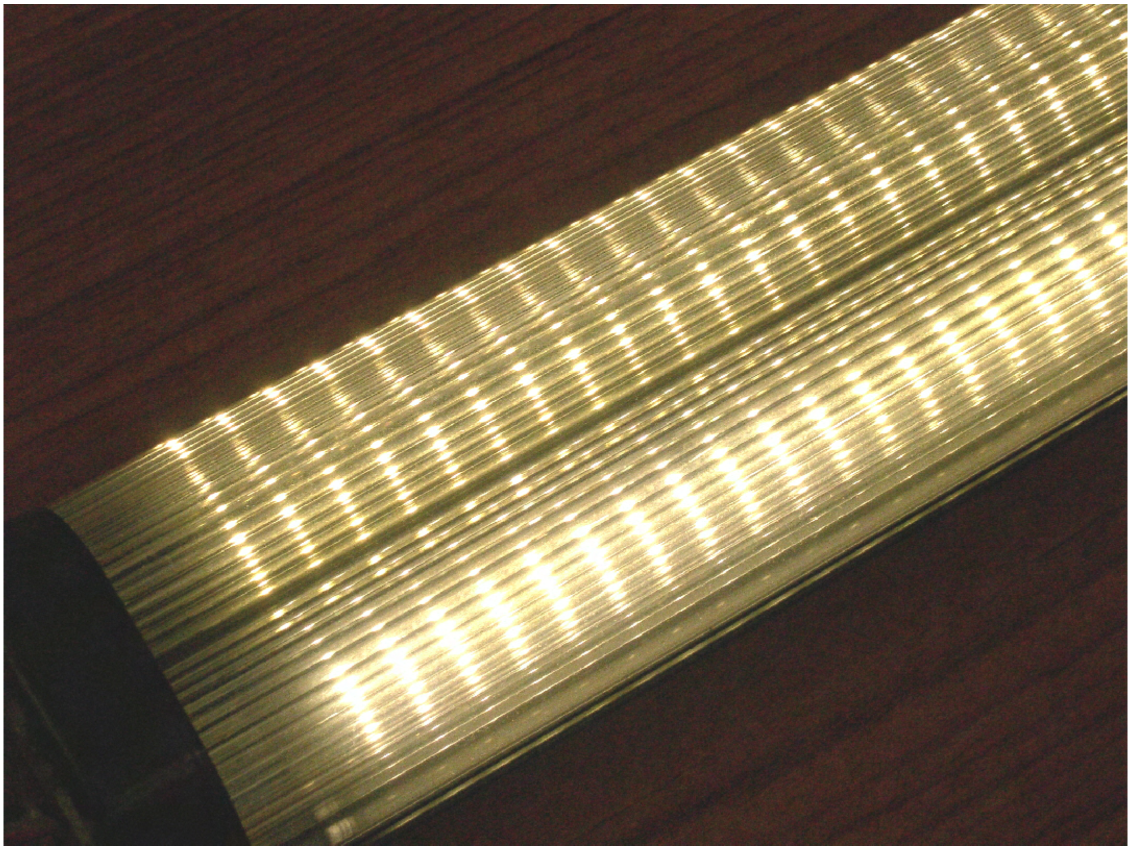
Advanced linear optics with ray tracing of tailored intensity pattern

Even LED Illumination is Superior to Fluorescents with no Glare

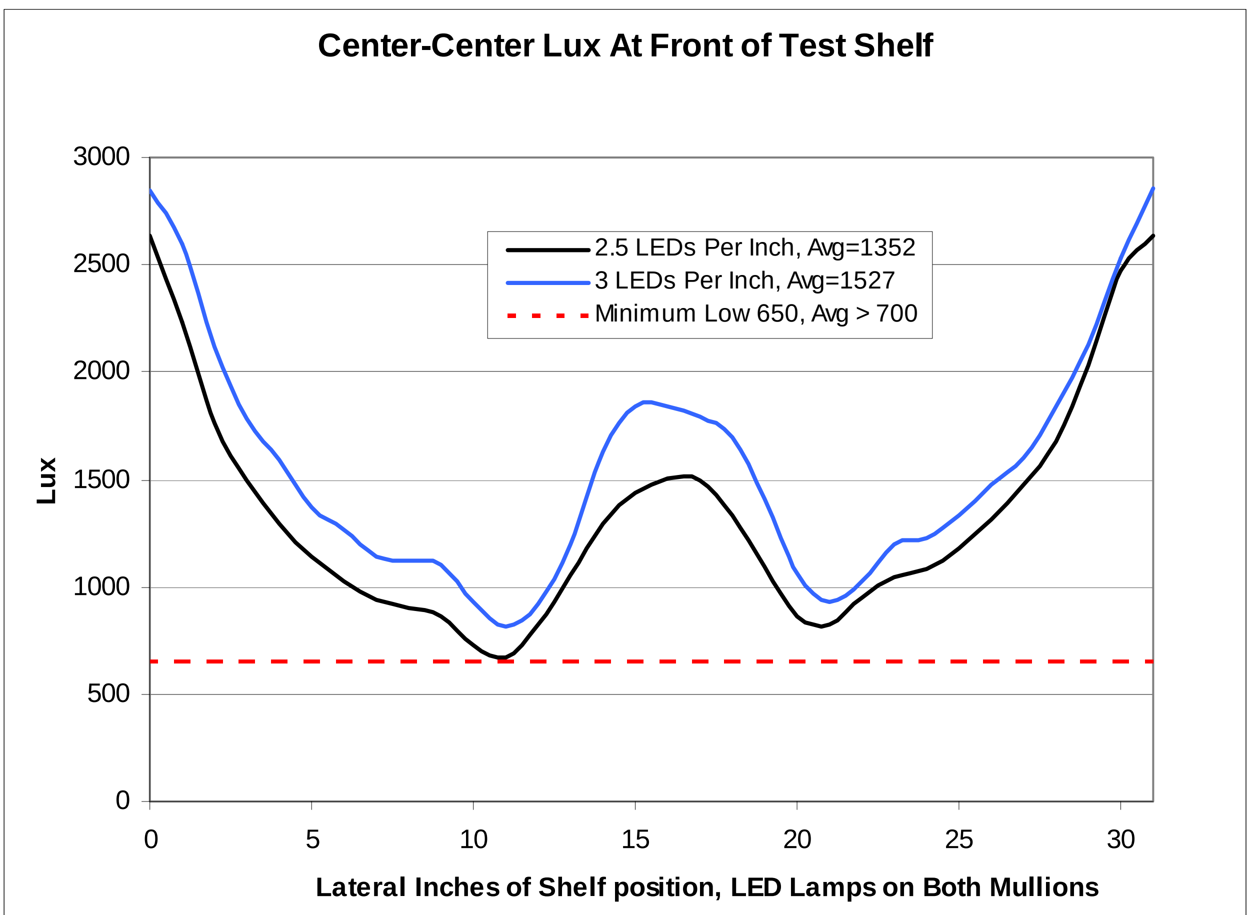


Electronic appearance when seen directly with no glare reflection.

REBATE-ELIGIBLE, MEETS ALL STANDARDS



Both light engines visible through Advanced Linear Optic



<terryp@energy-solution.com
>
01/31/2008 02:59 PM

To "Marc Theobald" <marc_theobald@emcorgroup.com>
cc "Cary Aberg" <caberg@ledpower.com>, "Mary M. Bryan" <marymattesonbryan@pacbell.net>
bcc
Subject Concord Costco Calculated Savings

History: This message has been replied to and forwarded.

Marc:

Attached is the last calculation used for Costco's evaluation and what I could find by way of specifications:

3 Door Case	**Non- System**		**Complete System**		
-	**Raw Led Lumen**	**Out put**	**Average system lumens**		
Kelvin Temperature	**4100K**	**WATTS**	**4100K**	**WATTS**	**Power Supply**
Lumens Per Led	**7 lm**	**W/O P/S**	**6 lm**	**W/ P/S**	**Watts**
SFBL-114-58"-41K-24	**798 lm**	**13 W**	**684 lm**	**15 W**	**80 watt**
DFBL-228-58"41K-24	**1596 lm**	**25.5 W**	**1368 lm**	**30 W**	**Power Supply**
DFBL-228-58"41K-24	**1596 lm**	**25.5 W**	**1368 lm**	**30 W**	**80 watt**
SFBL-114-58"-41K-24	**798 lm**	**13 W**	**684 lm**	**15 W**	**Power supply**
2 centers / 2 ends	**4,788**	**77 W**	**4,104**	**90 W**	**160**
	62.2 lm per watt		**45 lm per watt**		

Cary Abergis cc'd should you have more questions on the products.

Terry

Terry

[attachment "Costco LED 10-24-07.xls" deleted by Marc Theobald/EES/EMCORGROUP]
[attachment "LED Power - Freezer Case Tech Data.pdf" deleted by Marc Theobald/EES/EMCORGROUP]
[attachment "LED Power - Freezer Case Sales Data Sheet.pdf" deleted by Marc Theobald/EES/EMCORGROUP]

Appendix B
Photometric Test Protocol and Testing Results

Appendix B-1
Test Protocol

PG&E Emerging Technologies Lighting Demonstration Project
LED Refrigerated Case Lighting (CWA 07 CEE-T-4266)
Testing and Monitoring Plan - Costco

Testing Protocol for LED Lighting in Refrigerated Case Applications

I. Objective

This test protocol is intended to define a test procedure that will be applied to LED lighting in refrigerated case applications as part of the Emerging Technologies evaluation process.

II. Proposed Testing Areas

1. The LED strip lighting will be tested in (1) low temperature refrigerated case and (1) medium temperature refrigerated case located in the Costco in Concord, California. Additionally, contingent upon PG&E being able to supply a Dent Elite-Pro data logger, a second low temperature refrigerated case will be tested.

III. Performance Issues

The following issues have been recognized as critical to energy savings and long-term customer acceptance.

- Power Consumption
- Lifetime and Reliability
- Brightness and Light Quality

IV. Setup Protocol

1. Existing fluorescent lamps should be replaced with new fluorescent lamps and the new lamps must be “burned in” for at least 100 hours to stabilize the baseline condition.
2. Prior to taking lighting measurements, EMCOR Energy Services (EES) will designate measurement points in each test area by marking out a grid comprising at least three rows and three columns with an identifiable marker. EES will then take a digital image of each test area and measurements will be superimposed onto the digital image in order to create a measurement map. Preparation work should be done within off business hours, and coordinated with store manager for appropriate schedules.
3. Prior to taking lighting measurements, EES will document the specific measures taken to isolate the effect of changes to the test lighting systems from general lighting systems, which are not subject to change.
4. Costco Wholesale will not responsible for arranging electrician to install/remove the monitoring systems.

V. Tests Performed

The following tests shall be performed on existing lighting systems and the emerging technology (LED), with the exception of Task 4 of the test. Task 4 will be performed only for the emerging technology.

1. Measure Luminance
    a. Measure luminance values on the test grid with the doors closed using a Konica Minolta LS100 Luminance Meter.
    b. Record and report the characteristics of the surface of objects within the case on which the luminance measurements were performed, and the distance at which the measurements were taken.
    c. Luminance values will be indicated on luminance maps.

2. Measure Vertical Illuminance
   a. Measure and record illuminance values on the test grid area using a Konica Minolta CL200 Chroma Meter.
   b. Measurements will be taken directly in front of the shelving, at the location of the merchandise.

3. Determine Correlated Color Temperature
   a. Measure and record correlated color temperature on the test grid using a Konica Minolta CL200 Chroma Meter.

4. Determine Color Rendering Index (CRI)
   a. PG&E will coordinate with the California Lighting Technology Center (CLTC) to provide a sample lighting source to the CLTC lab for testing.
   b. EES will coordinate with the CLTC to obtain CRI test results and incorporate results into the report.

5. Determine Power Usage and System Run-Time
   a. Work with the host site to identify the circuit powering the test case.
   b. Oversee installation of a Dent Elite-Pro data logger by a licensed electrician. System power draw for existing fixtures and the emerging technology (LED) will each be monitored for approximately 7 days.
   c. EES will note dates of the system changeover.
   d. Oversee removal of the Dent Elite-Pro and evaluate the data collected.

6. Determine Refrigeration Energy Savings
   a. Work with the host to identify the compressor that provides cooling to the test refrigerated case and note other loads served by the compressor, if any.
   b. Record all pertinent nameplate data available for the compressor.
   c. Calculate refrigeration cooling savings based on compressor nameplate and other data. If the compressor coefficient of performance is not readily available, EES will assume a COP.

7. Customer Satisfaction
   a. EES will draft a brief written survey to help determine the level of customer satisfaction with the test installation.
   b. EES will present the survey to the host site management for approval.
   c. Upon management's approval, the survey will be administered to the host site's departmental sales staff, management, and maintenance personnel.

VI. Evaluation

Upon completion of testing, collected data will be evaluated to determine the energy savings and lighting performance of the emerging technology.

Appendix B-2
Measurement and Illuminance Maps

Base Case: Egg Crate Display Illuminance Readings

Base Case: Egg Crate Display Luminance Readings

Test Case: Egg Crate Display Illuminance Readings

Test Case: Egg Crate Display Luminance Readings

Base Case: Butter Display Illuminance Readings

Base Case: Butter Display Luminance Readings

Test Case: Butter Display Illuminance Readings

Test Case: Butter Display Luminance Readings

Appendix B-3
Laboratory Test Results

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REPORT NUMBER: ITL60172 DATE: 04/17/08
PREPARED FOR: RDS
CATALOG NUMBER: TDL 08-41

LUMINAIRE: EXTRUDED BLACK PAINTED INTERIOR HOUSING WITH MOLDED BLACK PLASTIC END CAPS, ONE HUNDRED THIRTY-EIGHT LEDS POTTED IN WHITE EPOXY ON EACH SIDE OF CENTER DIVIDER, EXTRUDED CLEAR PLASTIC LENS, LENS PRISMS OUT AND VERTICAL, OPEN ENDS.

LAMPS: TWO HUNDRED SEVENTY-SIX WHITE LIGHT EMITTING DIODES (LEDS) EACH WITH CLEAR SEMI-HEMISPHERICAL PLASTIC INTEGRAL LENS, LEDS VERTICALLY ALIGNED AIMED AT THE HORIZON AND CANTED 29-DEGREES FROM AIMED STRAIGHT AHEAD.

LED DRIVER: ADVANCE LEDINTA0024V41FO - 100W 24V 4.1ADC

MOUNTING: SURFACE

GONIOMETRIC INSTRUMENTATION:
ITL Moving Mirror Goniophotometer – 33.25 foot Test Distance
Valhalla Scientific 2100 Digital Power Analyzer
Elgar CW2501 AC Power Source
Omega HH-81 Digital Thermometer with Type J thermocouples

OBJECT OF TEST: Measure distribution photometry and input electrical parameters on the goniophotometer. Report candela distribution, efficacy and calculated lumen output.

PROCEDURE: The luminaire was supplied by client with an unknown number of burn hours. The luminaire was prewarmed overnight on the test apparatus before being tested. Stabilization data was recorded just prior to testing to assure stabile operation (stabilization data available on request). Distribution photometry and input electrical data were measured with the luminaire mounted on the goniophotometer. All data are traceable to the National Institute of Standards and Technology. All testing performed with the luminaire operated at 120V AC in a 25 +/-1 degree Celsius free air ambient.

NOTE: This luminaire was tested with the length of the luminaire in the horizontal plane and aimed at nadir. After gathering the data in this position, the data was tilted 90-degrees to represent a vertical luminaire aimed straight ahead towards the horizon (see the note and drawing on the next page for more information).

Checked: *R BERGIN*
Approved: *R BEATTIE*

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PREPARED FOR: RDS

CATALOG NUMBER: TDL 08-41

LUMINAIRE: EXTRUDED BLACK PAINTED INTERIOR HOUSING WITH MOLDED BLACK PLASTIC END CAPS, ONE HUNDRED THIRTY-EIGHT LEDS POTTED IN WHITE EPOXY ON EACH SIDE OF CENTER DIVIDER, EXTRUDED CLEAR PLASTIC LENS, LENS PRISMS OUT AND VERTICAL, OPEN ENDS.

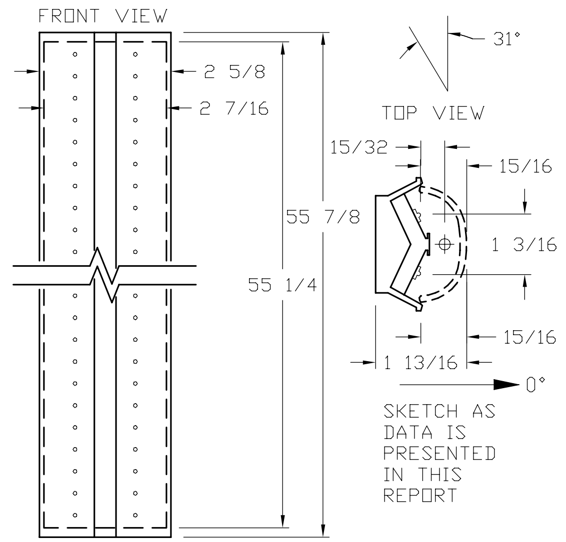
LAMPS: TWO HUNDRED SEVENTY-SIX WHITE LIGHT EMITTING DIODES (LEDS) EACH WITH CLEAR SEMI-HEMISPHERICAL PLASTIC INTEGRAL LENS, LEDS VERTICALLY ALIGNED AIMED AT THE HORIZON AND CANTED 31-DEGREES FROM AIMED STRAIGHT AHEAD.

TOTAL INPUT WATTS = 36.1 AT 120.0 VOLTS, 0.308 AMPS

MOUNTING: SURFACE

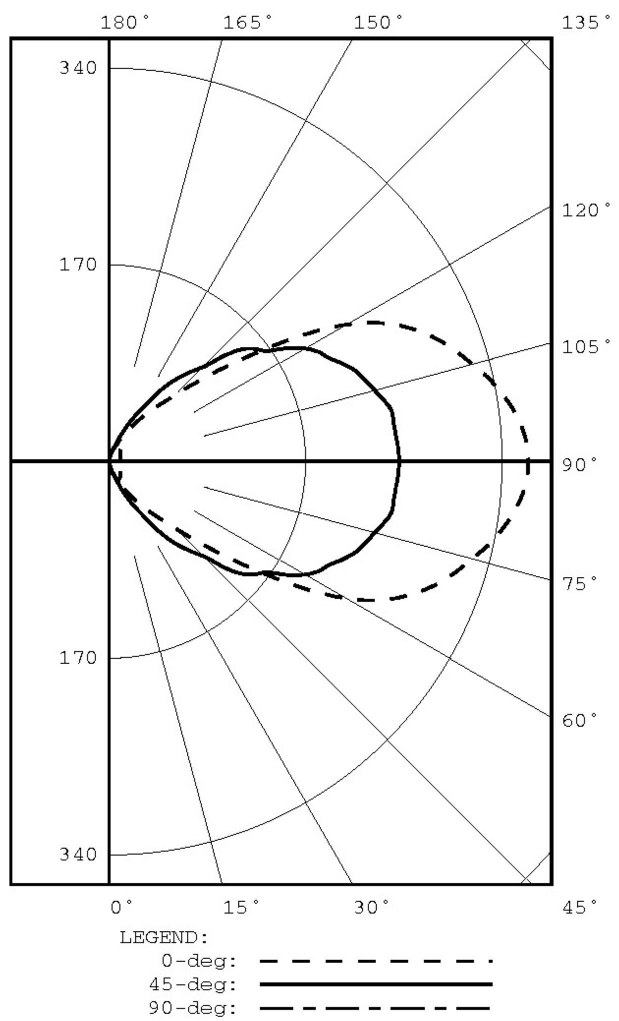
LED DRIVER: ADVANCE LEDINTA0024V41FO - 100W 24V 4.1ADC

NOTE: DATA SHOWN IS ABSOLUTE FOR THE SAMPLE PROVIDED AT RATED INPUT VOLTAGE (120VAC) TO THE LED DRIVER. THIS LUMINAIRE WAS TESTED HORIZONTALLY AIMED AT NADIR. A FACTOR WAS DERIVED FROM A STABLE LIGHT OUTPUT MEASUREMENT WITH THE LUMINAIRE HORIZONTAL, COMPARED TO ANOTHER STABLE LIGHT OUTPUT MEASUREMENT (AT THE SAME ANGULAR LOCATION RELATIVE TO THE LUMINAIRE) WITH THE LUMINAIRE VERTICAL. THIS FACTOR WAS APPLIED TO THE DATA TO CORRECT THE HORIZONTAL LUMINAIRE DATA TO REPRESENT THE PERFORMANCE OF A VERTICAL LUMINAIRE AIMED STRAIGHT AHEAD TOWARDS THE HORIZON.



CANDELA DISTRIBUTION

	0.0	45.0	90.0	135.0	180.0	FLUX
0	0	0	0	0	0	
5	2	2	2	0	0	0
15	10	9	7	1	0	1
25	17	29	18	2	0	7
35	42	71	16	2	0	27
45	83	116	14	2	0	56
55	176	167	13	2	0	88
65	278	211	12	2	0	113
75	325	238	12	2	0	125
85	358	249	12	2	0	131
90	362	252	12	2	0	
95	358	249	12	2	0	131
105	325	238	12	2	0	125
115	278	211	12	2	0	113
125	176	167	13	2	0	88
135	83	116	14	2	0	56
145	42	71	16	2	0	27
155	17	29	18	2	0	7
165	10	9	7	1	0	1
175	2	2	2	0	0	0
180	0	0	0	0	0	



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ZONAL LUMEN SUMMARY

ZONE	LUMENS	%FIXT
0- 30	10	0.9
0- 40	37	3.4
0- 60	183	16.5
0- 90	552	50.0
90-120	370	33.5
90-130	459	41.5
90-150	543	49.1
90-180	552	50.0
0-180	1105	100.0

EFFICACY = 30.61 Lm/W
CIE TYPE - DIRECT-INDIRECT

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CANDELA DISTRIBUTION

LATERAL ANGLE

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	65.0	75.0	85.0	90.0	95.0	105.0	115.0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	2	2	2	2	2	2	1	1	1	1	1	1	1	1
5.0	2	2	2	2	2	2	2	2	2	2	2	2	1	1
7.5	5	5	5	4	4	3	3	3	3	3	3	3	2	2
10.0	6	6	6	5	6	6	5	5	5	5	4	4	3	2
12.5	8	8	7	7	7	7	7	6	6	6	6	5	4	2
15.0	10	10	9	9	9	9	9	8	7	7	7	6	5	3
17.5	11	11	11	12	12	11	10	14	14	11	10	8	5	3
20.0	13	13	13	15	15	14	18	25	25	16	13	10	6	4
22.5	14	15	16	18	18	21	26	34	37	20	15	12	7	4
25.0	17	19	21	23	23	29	34	42	50	25	18	13	7	5
27.5	23	24	27	29	32	38	43	53	55	25	18	13	8	5
30.0	29	30	34	37	42	47	58	107	56	25	17	13	8	6
32.5	36	37	43	46	52	57	96	176	63	24	17	12	9	6
35.0	42	44	54	59	64	71	119	247	78	24	16	12	9	6
37.5	51	53	67	73	77	84	133	323	85	22	16	12	9	7
40.0	60	65	84	87	89	95	145	305	77	20	15	12	10	7
42.5	69	80	101	101	100	106	174	349	64	18	14	11	11	7
45.0	83	99	119	114	110	116	199	464	48	16	14	11	11	7
47.5	100	120	133	125	120	136	208	559	38	15	13	11	11	7
50.0	121	141	145	139	131	151	227	550	37	15	13	12	12	8
52.5	146	162	157	149	143	160	238	581	35	15	13	12	12	8
55.0	176	184	166	157	153	167	251	628	31	14	13	12	13	8
57.5	208	205	172	165	160	182	271	652	30	14	12	12	14	8
60.0	237	223	175	174	167	196	294	642	33	15	12	12	14	8
62.5	260	241	183	181	170	205	291	647	34	15	12	12	14	7
65.0	278	259	195	187	174	211	292	667	35	15	12	12	14	7
67.5	292	272	202	188	184	220	300	641	36	15	12	12	14	7
70.0	305	282	202	191	190	228	307	610	36	15	12	12	14	7
72.5	315	293	211	202	192	233	303	589	36	15	12	12	14	7
75.0	325	304	217	201	194	238	302	576	36	15	12	11	15	7
77.5	336	314	221	206	197	244	304	567	37	15	12	12	15	7
80.0	344	321	222	207	200	248	305	557	38	15	12	12	15	7
82.5	352	325	227	205	201	248	303	550	39	15	12	12	15	7
85.0	358	336	228	210	202	249	300	545	40	15	12	12	15	7
87.5	362	327	230	215	202	250	298	548	39	15	12	12	16	7
90.0	362	332	230	214	201	252	296	553	39	14	12	12	16	7
92.5	362	327	230	215	202	250	298	548	39	15	12	12	16	7
95.0	358	336	228	210	202	249	300	545	40	15	12	12	15	7
97.5	352	325	227	205	201	248	303	550	39	15	12	12	15	7
100.0	344	321	222	207	200	248	305	557	38	15	12	12	15	7
102.5	336	314	221	206	197	244	304	567	37	15	12	12	15	7
105.0	325	304	217	201	194	238	302	576	36	15	12	11	15	7
107.5	315	293	211	202	192	233	303	589	36	15	12	12	14	7
110.0	305	282	202	191	190	228	307	610	36	15	12	12	14	7
112.5	292	272	202	188	184	220	300	641	36	15	12	12	14	7
115.0	278	259	195	187	174	211	292	667	35	15	12	12	14	7
117.5	260	241	183	181	170	205	291	647	34	15	12	12	14	7
120.0	237	223	175	174	167	196	294	642	33	15	12	12	14	8
122.5	208	205	172	165	160	182	271	652	30	14	12	12	14	8
125.0	176	184	166	157	153	167	251	628	31	14	13	12	13	8
127.5	146	162	157	149	143	160	238	581	35	15	13	12	12	8
130.0	121	141	145	139	131	151	227	550	37	15	13	12	12	8
132.5	100	120	133	125	120	136	208	559	38	15	13	11	11	7
135.0	83	99	119	114	110	116	199	464	48	16	14	11	11	7
137.5	69	80	101	101	100	106	174	349	64	18	14	11	11	7
140.0	60	65	84	87	89	95	145	305	77	20	15	12	10	7
142.5	51	53	67	73	77	84	133	323	85	22	16	12	9	7
145.0	42	44	54	59	64	71	119	247	78	24	16	12	9	6
147.5	36	37	43	46	52	57	96	176	63	24	17	12	9	6
150.0	29	30	34	37	42	47	58	107	56	25	17	13	8	6
152.5	23	24	27	29	32	38	43	53	55	25	18	13	8	5
155.0	17	19	21	23	23	29	34	42	50	25	18	13	7	5
157.5	14	15	16	18	18	21	26	34	37	20	15	12	7	4
160.0	13	13	13	15	15	14	18	25	25	16	13	10	6	4

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CANDELA DISTRIBUTION
LATERAL ANGLE

	0.0	5.0	15.0	25.0	35.0	45.0	55.0	65.0	75.0	85.0	90.0	95.0	105.0	115.0
162.5	11	11	11	12	12	11	10	14	14	11	10	8	5	3
165.0	10	10	9	9	9	9	9	8	7	7	7	6	5	3
167.5	8	8	7	7	7	7	7	6	6	6	6	5	4	2
170.0	6	6	6	5	6	6	5	5	5	5	4	4	3	2
172.5	5	5	5	4	4	3	3	3	3	3	3	3	2	2
175.0	2	2	2	2	2	2	2	2	2	2	2	2	1	1
177.5	2	2	2	2	2	2	1	1	1	1	1	1	1	1
180.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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CANDELA DISTRIBUTION
LATERAL ANGLE

	125.0	135.0	145.0	155.0	165.0	175.0	180.0
0.0	0	0	0	0	0	0	0
2.5	1	0	0	0	0	0	0
5.0	1	0	0	0	0	0	0
7.5	1	0	0	0	0	0	0
10.0	1	1	0	0	0	0	0
12.5	2	1	0	0	0	0	0
15.0	2	1	0	0	0	0	0
17.5	2	1	0	0	0	0	0
20.0	2	1	0	0	0	0	0
22.5	2	1	0	0	0	0	0
25.0	3	2	0	0	0	0	0
27.5	3	2	0	0	0	0	0
30.0	3	2	0	0	0	0	0
32.5	4	2	0	0	0	0	0
35.0	4	2	0	0	0	0	0
37.5	4	2	0	0	0	0	0
40.0	4	2	0	0	0	0	0
42.5	4	2	0	0	0	0	0
45.0	4	2	0	0	0	0	0
47.5	4	2	0	0	0	0	0
50.0	3	1	0	0	0	0	0
52.5	3	2	0	0	0	0	0
55.0	3	2	0	0	0	0	0
57.5	4	1	0	0	0	0	0
60.0	4	2	0	0	0	0	0
62.5	4	2	0	0	0	0	0
65.0	4	2	0	0	0	0	0
67.5	4	2	0	0	0	0	0
70.0	4	2	0	0	0	0	0
72.5	4	2	0	0	0	0	0
75.0	3	2	0	0	0	0	0
77.5	3	2	0	0	0	0	0
80.0	3	2	0	0	0	0	0
82.5	4	2	0	0	0	0	0
85.0	4	2	0	0	0	0	0
87.5	4	2	0	0	0	0	0
90.0	4	2	0	0	0	0	0
92.5	4	2	0	0	0	0	0
95.0	4	2	0	0	0	0	0
97.5	4	2	0	0	0	0	0
100.0	3	2	0	0	0	0	0
102.5	3	2	0	0	0	0	0
105.0	3	2	0	0	0	0	0
107.5	4	2	0	0	0	0	0
110.0	4	2	0	0	0	0	0
112.5	4	2	0	0	0	0	0
115.0	4	2	0	0	0	0	0
117.5	4	2	0	0	0	0	0
120.0	4	2	0	0	0	0	0
122.5	4	1	0	0	0	0	0
125.0	3	2	0	0	0	0	0
127.5	3	2	0	0	0	0	0
130.0	3	1	0	0	0	0	0
132.5	4	2	0	0	0	0	0
135.0	4	2	0	0	0	0	0
137.5	4	2	0	0	0	0	0
140.0	4	2	0	0	0	0	0
142.5	4	2	0	0	0	0	0
145.0	4	2	0	0	0	0	0
147.5	4	2	0	0	0	0	0
150.0	3	2	0	0	0	0	0
152.5	3	2	0	0	0	0	0
155.0	3	2	0	0	0	0	0
157.5	2	1	0	0	0	0	0
160.0	2	1	0	0	0	0	0

CANDELA DISTRIBUTION

LATERAL ANGLE

	125.0	135.0	145.0	155.0	165.0	175.0	180.0
162.5	2	1	0	0	0	0	0
165.0	2	1	0	0	0	0	0
167.5	2	1	0	0	0	0	0
170.0	1	1	0	0	0	0	0
172.5	1	0	0	0	0	0	0
175.0	1	0	0	0	0	0	0
177.5	1	0	0	0	0	0	0
180.0	0	0	0	0	0	0	0

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COEFFICIENTS OF UTILIZATION - ZONAL CAVITY METHOD

EFFECTIVE FLOOR CAVITY REFLECTANCE 0.20

RC	80				70				50			30			10			0
RW	70	50	30	10	70	50	30	10	50	30	10	50	30	10	50	30	10	0
0	107	107	107	107	99	99	99	99	83	83	83	69	69	69	56	56	56	50
1	91	84	78	72	83	77	71	66	63	59	55	51	48	45	40	37	35	29
2	80	70	61	54	73	64	56	49	52	46	41	41	36	32	31	27	24	19
3	72	59	50	42	65	54	45	38	44	37	31	34	29	24	25	21	18	13
4	65	51	41	33	58	46	37	30	37	30	25	29	24	19	21	17	14	10
5	59	45	35	27	53	40	32	25	33	25	20	25	20	15	19	14	11	7
6	54	39	30	23	48	36	27	21	29	22	17	22	17	13	16	12	9	5
7	49	35	26	19	44	32	23	17	26	19	14	20	15	10	15	10	7	4
8	45	31	22	16	41	28	20	15	23	17	12	18	13	9	13	9	6	3
9	42	28	20	14	38	26	18	13	21	15	10	16	11	8	12	8	5	3
10	39	26	18	12	35	23	16	11	19	13	9	15	10	7	11	7	4	2

ALL CANDELA, LUMENS, LUMINANCE, AND VCP VALUES IN THIS REPORT ARE BASED ON ABSOLUTE PHOTOMETRY. THE COEFFICIENT OF UTILIZATION VALUES ARE BASED ON THE TOTAL ABSOLUTE LUMEN OUTPUT OF THIS LUMINAIRE SAMPLE.

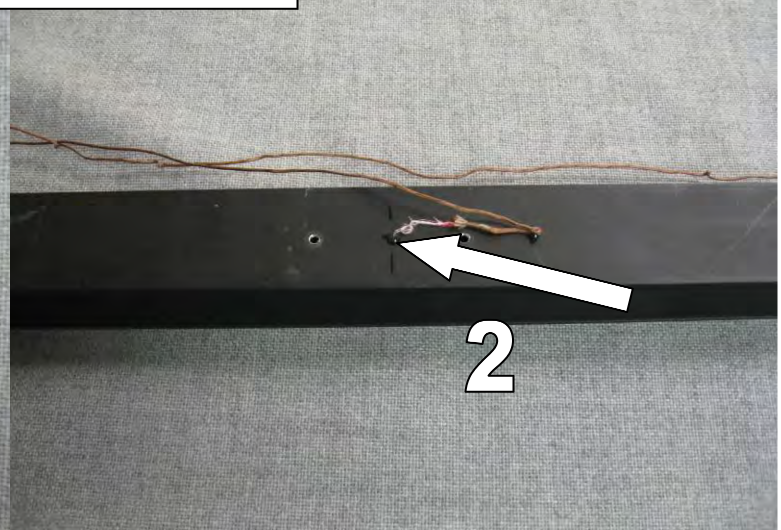
NOTE: THE ZONAL CAVITY CALCULATION TECHNIQUE IS ACCURATE WHEN LUMINAIRES WITH SYMMETRIC CANDELA DISTRIBUTIONS ARE EMPLOYED AND WHEN THE LUMINAIRES ARE LOCATED SYMMETRICALLY THROUGHOUT THE ROOM. THIS UNIT HAS SPECIAL CHARACTERISTICS AND THEREFORE THESE COEFFICIENTS SHOULD BE USED WITH CAUTION.

Temperature Measurements

Measurements taken with the luminaire in the vertical position:

At thermocouple #1 location (top): 35.7°C
At thermocouple #2 location (middle): 34.7°C

THERMOCOUPLE
ATTACHMENT POINT



PHOTOGRAPHS

LUMINAIRE – SIDE VIEW

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LUMINAIRE – FRONT VIEW

ADDITIONAL NOTES: Stabilization data was recorded for approximately one hour prior to the test to ensure complete stabilization prior to testing. If RDS would like this data supplied, please notify ITL and we will supply the data needed

Total time this unit was energized for all testing is 56.5 hours.

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REPORT NUMBER: ITL60197 DATE: 04/21/08

PREPARED FOR: RDS

CATALOG NUMBER: TDL 08-42

LUMINAIRE: EXTRUDED BLACK PAINTED INTERIOR HOUSING WITH MOLDED BLACK PLASTIC END CAPS, FORTY-EIGHT LEDS POTTED IN WHITE EPOXY ON BOTH SIDES OF CENTER DIVIDER, EXTRUDED CLEAR PLASTIC LENS, LENS PRISMS OUT AND VERTICAL, OPEN ENDS.

LAMP: FORTY-EIGHT WHITE LIGHT EMITTING DIODES (LEDS) EACH WITH CLEAR SEMI-HEMISPHERICAL PLASTIC INTEGRAL LENS, LEDS VERTICALLY ALIGNED AIMED AT THE HORIZON AND CANTED 29-DEGREES FROM AIMED STRAIGHT AHEAD.

LED DRIVER: ADVANCE LEDINTA0024V41FO - 100W 24V 3.3ADC

MOUNTING: SURFACE

SPECTRORADIOMETRIC INSTRUMENTATION:
Yokogawa WT210 Digital Power Meter
Optronic Laboratories OL770 Spectroradiometer
1.5 meter integrating sphere
Elgar CW1251 AC Power Source
Omega HH-81 Digital Thermometer with Type J thermocouples

OBJECT OF TEST: Measure the total flux output in lumens, Correlated Color Temperature (CCT), Color Rendering Index (CRI), Chromaticity Coordinates (x/y; u'/v'), and Spectral Power Distribution (SPD) of the lamp and input electrical parameters when operated in the integrating sphere. Measure surface temperature of the lamp at two locations.

PROCEDURE: The lamp was supplied by client with an unknown number of burn hours. The lamp was prewarmed overnight before each test. Stabilization data was recorded to assure stabile operation (stabilization data available on request). CCT, CRI, x/y and u'/v' chromaticity coordinates, SPD, total flux, and input electrical data were measured with the lamp operating in the integrating sphere. In order to measure the mean performance, twenty data sets were averaged using the Optronics OL770. Two Type J thermocouples were attached to the surface of the lamp to measure operating temperature (see photograph in the report for locations). All data are traceable to the National Institute of Standards and Technology. All testing performed with the lamp operated at 120V AC in a 25 +/-1 degree Celsius free air ambient.

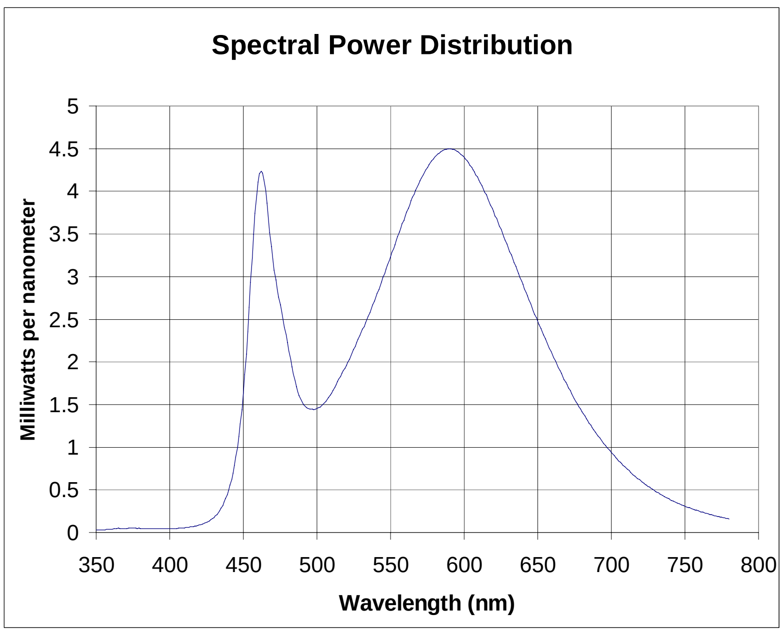
Checked: *N GULLY*
Approved: *R BERGIN*

THE LIGHT CENTER OF THE INDUSTRY SINCE 1955
INDEPENDENT TESTING LABORATORIES, INC.
3386 LONGHORN ROAD, BOULDER, CO 80302 USA
PHONE: (303)442-1255 • FAX: (303)449-5274 • E-MAIL: itl@itlboulder.com • WEBSITE: www.itlboulder.com

PREPARED FOR: RDS
CATALOG NUMBER: TDL 08-42

RESULTS:

SPECTRORADIOMETRIC TESTING IN INTEGRATING SPHERE	
PHOTOMETRIC	
Total Integrated Flux (Lumens)	238*
SPECTRORADIOMETRIC	
Observer	CIE 1931 2 degree
Chromaticity Ordinate x	0.4051
Chromaticity Ordinate y	0.3875
Observer	CIE 1976 2 degree
Chromaticity Ordinate u’	0.2369
Chromaticity Ordinate v’	0.5099
Correlated Color Temp CCT (K)	3478
Color Rendering Index (CRI)	79
Total Radiant Flux (milliWatts)	753
ELECTRICAL	
Input Voltage (Volts AC)	120.0
Input Current (mA AC)	85
Input Power (Watts)	9.39
EFFICACY	
Lumens/Watt	25.35



*NOTE: Proper calibration of integrating spheres for measuring total flux output of non-directional lamps will produce reliable, repeatable results within the calibration tolerances of the equipment used. However, measurement of lamps with significant self absorption and/or directional output, even when these effects are compensated for, are likely to have a greater variation in results compared to the flux output calculated from a goniophotometric exploration since these artifacts do not affect the goniophotometric results. For this test, the integrating sphere was calibrated using a directional incandescent flux standard with a distribution similar to the luminaire under test, per IESNA LM78-06.

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CATALOG NUMBER: TDL 08-42

RESULTS:

Tabulated Spectral Power Distribution

Wavelength (nm)	mWatts/nm	Wavelength (nm)	mWatts/nm
350.0	0.02973	570.0	4.12045
360.0	0.03674	580.0	4.39811
370.0	0.04710	590.0	4.49542
380.0	0.04739	600.0	4.39693
390.0	0.04452	610.0	4.13184
400.0	0.04544	620.0	3.76001
410.0	0.05556	630.0	3.33872
420.0	0.08660	640.0	2.90543
430.0	0.17594	650.0	2.47418
440.0	0.49588	660.0	2.08409
450.0	1.63259	670.0	1.73118
460.0	4.10475	680.0	1.41999
470.0	3.20563	690.0	1.15497
480.0	2.22367	700.0	0.93790
490.0	1.52581	710.0	0.75630
500.0	1.45164	720.0	0.60434
510.0	1.63520	730.0	0.48294
520.0	1.96022	740.0	0.38564
530.0	2.34387	750.0	0.30882
540.0	2.75856	760.0	0.24799
550.0	3.23090	770.0	0.19742
560.0	3.70935	780.0	0.15841

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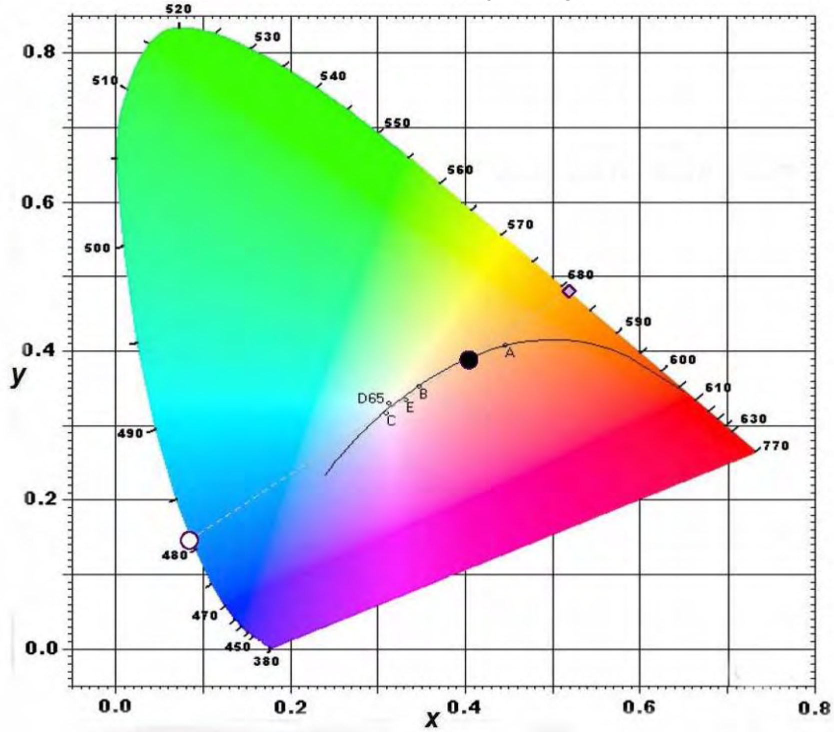
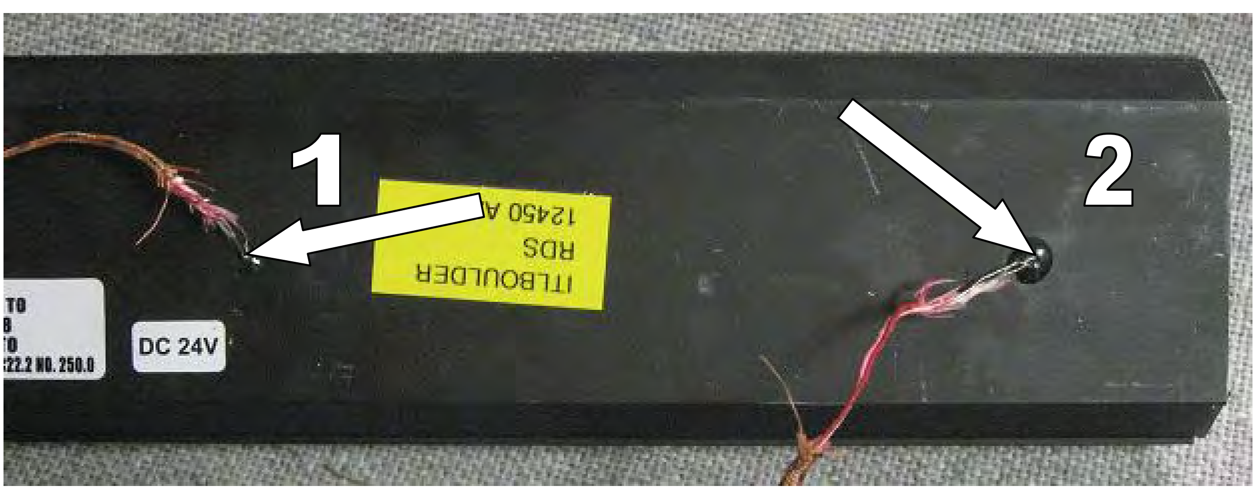
CIE Chromaticity Diagram



Temperature Measurements

At thermocouple #1 location (center): 32.7°C
At thermocouple #2 location (upper): 33.5°C

THERMOCOUPLE
ATTACHMENT POINT



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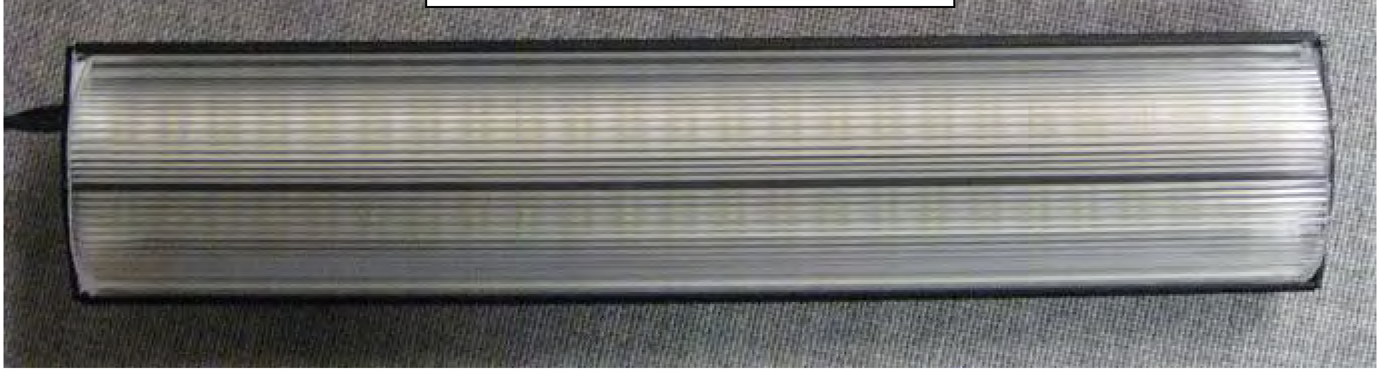
PHOTOGRAPHS

LUMINAIRE – BOTTOM VIEW



LUMINAIRE – FULL VIEW

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ADDITIONAL NOTES: Stabilization data was recorded for approximately one hour prior to each test on each apparatus to ensure complete stabilization prior to testing. If RDS would like this data supplied, please notify ITL and we will supply the data needed

Total time this unit was energized for all testing is 63.5 hours.

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REPORT NUMBER: ITL60198 DATE: 04/22/08

PREPARED FOR: RDS

CATALOG NUMBER: TDL 08-43

LUMINAIRE: EXTRUDED BLACK PAINTED INTERIOR HOUSING WITH MOLDED BLACK PLASTIC END CAPS, SIXTY LEDS POTTED IN WHITE EPOXY ON BOTH SIDES OF CENTER DIVIDER, EXTRUDED CLEAR PLASTIC LENS, LENS PRISMS OUT AND VERTICAL, OPEN ENDS.

LAMP: SIXTY WHITE LIGHT EMITTING DIODES (LEDS) EACH WITH CLEAR SEMI-HEMISPHERICAL PLASTIC INTEGRAL LENS, LEDS VERTICALLY ALIGNED AIMED AT THE HORIZON AND CANTED 29-DEGREES FROM AIMED STRAIGHT AHEAD.

LED DRIVER: ADVANCE LEDINTA0024V41FO - 100W 24V 3.3ADC

MOUNTING: SURFACE

SPECTRORADIOMETRIC
INSTRUMENTATION:
Yokogawa WT210 Digital Power Meter
Optronic Laboratories OL770 Spectroradiometer
1.5 meter integrating sphere
Elgar CW1251 AC Power Source
Omega HH-81 Digital Thermometer with Type J thermocouples

OBJECT OF TEST: Measure the total flux output in lumens, Correlated Color Temperature (CCT), Color Rendering Index (CRI), Chromaticity Coordinates (x/y; u'/v'), and Spectral Power Distribution (SPD) of the lamp and input electrical parameters when operated in the integrating sphere. Measure surface temperature of the lamp at two locations.

PROCEDURE: The lamp was supplied by client with an unknown number of burn hours. The lamp was prewarmed overnight before each test. Stabilization data was recorded to assure stabile operation (stabilization data available on request). CCT, CRI, x/y and u'/v' chromaticity coordinates, SPD, total flux, and input electrical data were measured with the lamp operating in the integrating sphere. In order to measure the mean performance, twenty data sets were averaged using the Optronics OL770. Two Type J thermocouples were attached to the surface of the lamp to measure operating temperature (see photograph in the report for locations). All data are traceable to the National Institute of Standards and Technology. All testing performed with the lamp operated at 120V AC in a 25 +/-1 degree Celsius free air ambient.

Checked: *N GULLY*
Approved: *R BERGIN*

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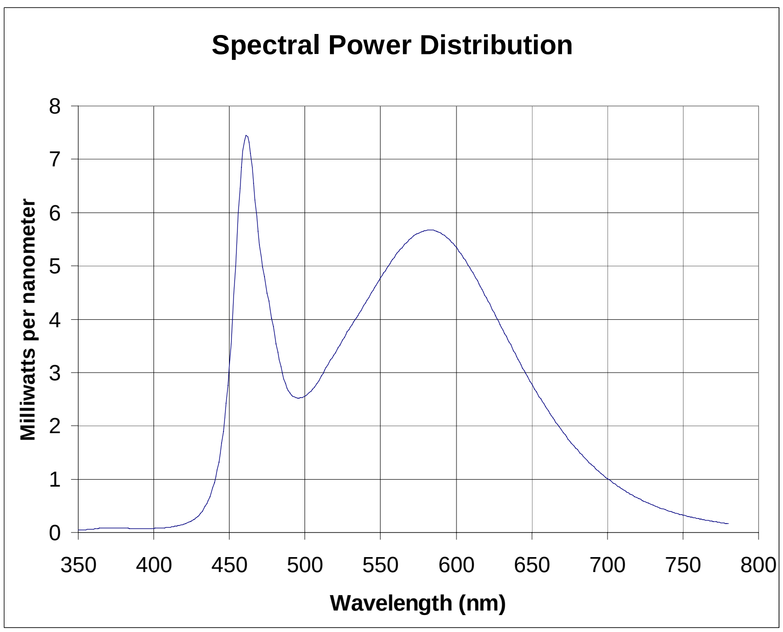
PREPARED FOR: RDS
CATALOG NUMBER: TDL 08-43

RESULTS:

SPECTRORADIOMETRIC TESTING IN INTEGRATING SPHERE	
PHOTOMETRIC	
Total Integrated Flux (Lumens)	330*
SPECTRORADIOMETRIC	
Observer	CIE 1931 2 degree
Chromaticity Ordinate x	0.3683
Chromaticity Ordinate y	0.3752
Observer	CIE 1976 2 degree
Chromaticity Ordinate u’	0.2178
Chromaticity Ordinate v’	0.4991
Correlated Color Temp CCT (K)	4334
Color Rendering Index (CRI)	80
Total Radiant Flux (milliWatts)	1038
ELECTRICAL	
Input Voltage (Volts AC)	120.0
Input Current (mA AC)	97
Input Power (Watts)	10.84
EFFICACY	
Lumens/Watt	30.44



*NOTE: Proper calibration of integrating spheres for measuring total flux output of non-directional lamps will produce reliable, repeatable results within the calibration tolerances of the equipment used. However, measurement of lamps with significant self absorption and/or directional output, even when these effects are compensated for, are likely to have a greater variation in results compared to the flux output calculated from a goniophotometric exploration since these artifacts do not affect the goniophotometric results. For this test, the integrating sphere was calibrated using a directional incandescent flux standard with a distribution similar to the luminaire under test, per IESNA LM78-06.

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PREPARED FOR: RDS

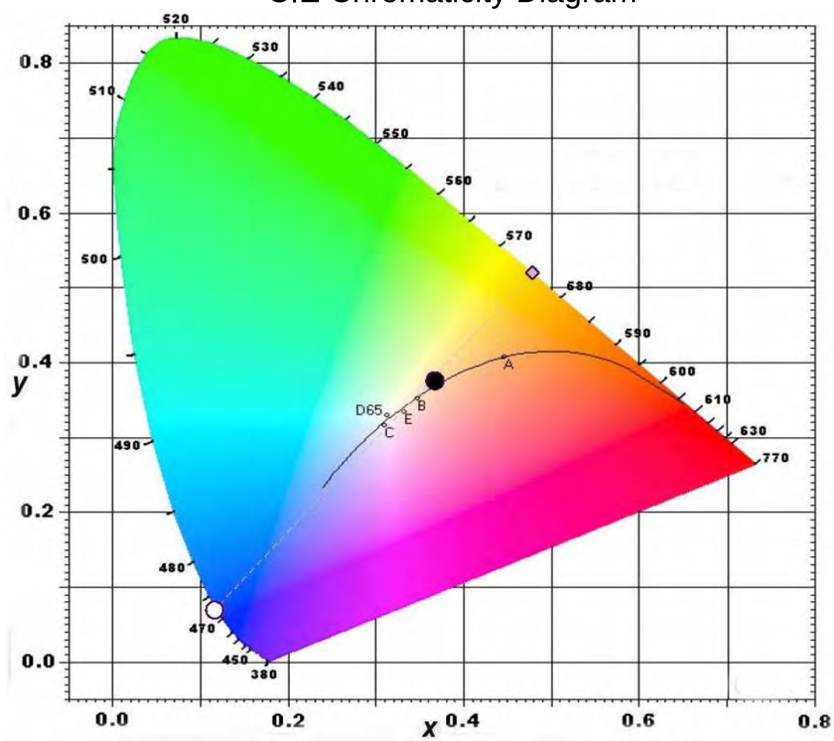
CATALOG NUMBER: TDL 08-43

RESULTS:

Tabulated Spectral Power Distribution

Wavelength (nm)	mWatts/nm	Wavelength (nm)	mWatts/nm
350.0	0.04980	570.0	5.51617
360.0	0.06170	580.0	5.66624
370.0	0.07912	590.0	5.61095
380.0	0.08272	600.0	5.34846
390.0	0.07578	610.0	4.92123
400.0	0.07720	620.0	4.39876
410.0	0.09820	630.0	3.84606
420.0	0.15819	640.0	3.30255
430.0	0.32966	650.0	2.78569
440.0	0.93739	660.0	2.32104
450.0	3.12414	670.0	1.91032
460.0	7.35320	680.0	1.55355
470.0	5.39307	690.0	1.25670
480.0	3.70124	700.0	1.01316
490.0	2.61619	710.0	0.81242
500.0	2.55797	720.0	0.64727
510.0	2.88675	730.0	0.51394
520.0	3.36755	740.0	0.40881
530.0	3.85427	750.0	0.32671
540.0	4.30939	760.0	0.26109
550.0	4.77313	770.0	0.20749
560.0	5.20060	780.0	0.16533

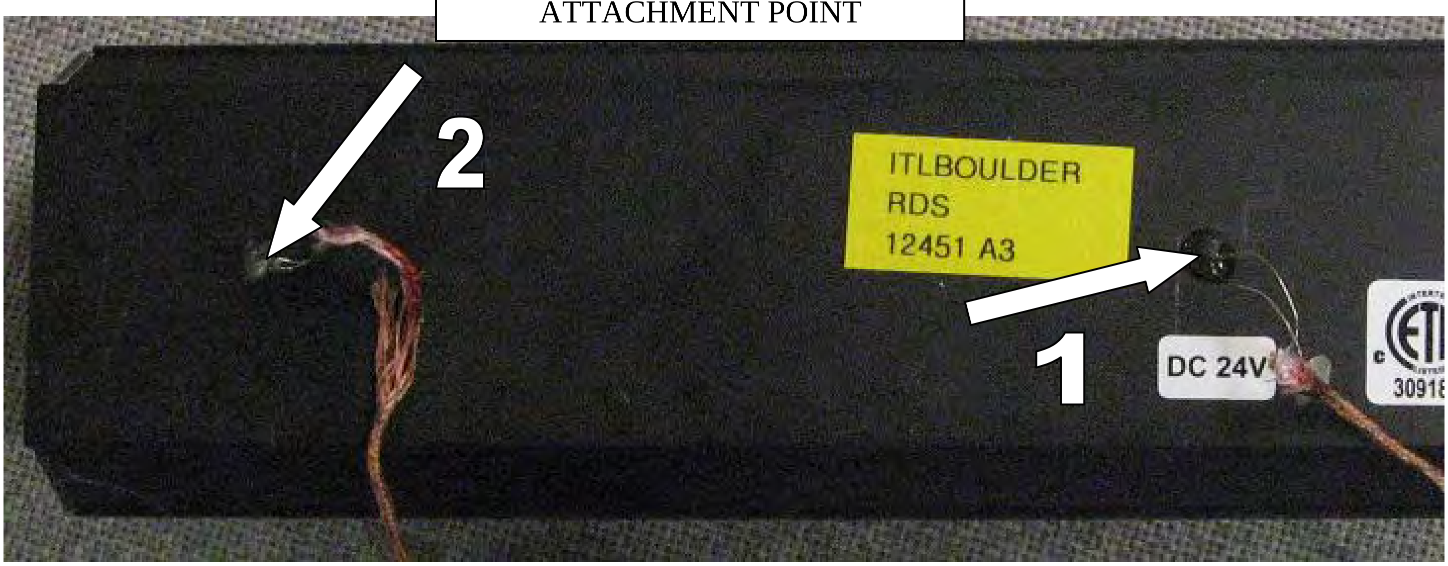
CIE Chromaticity Diagram



Temperature Measurements

```
At thermocouple #1 location (center):     34.9°C
At thermocouple #2 location (top):        35.2°C
```

THERMOCOUPLE
ATTACHMENT POINT



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PHOTOGRAPHS

LUMINAIRE – BOTTOM VIEW

LUMINAIRE – FULL VIEW

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ADDITIONAL NOTES: Stabilization data was recorded for approximately one hour prior to each test on each apparatus to ensure complete stabilization prior to testing. If RDS would like this data supplied, please notify ITL and we will supply the data needed

Total time this unit was energized for all testing is 23.5 hours.

Appendix C
Calculations

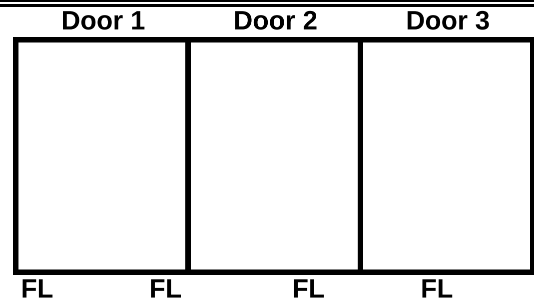
Appendix C-1
System Efficacy

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Efficacy Summary

System Configurations

Base case: typical 3-door set -------->

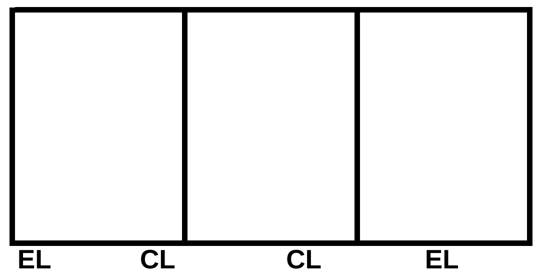
FL - Fluorescent rated@ 40W/ea.
.
4L x ~40W = 160W



Test case: typical 3-door set ---------->

CL: Center LED (228) ~30W
EL: End LED (114) LED ~15W

(2) x ~15W + (2) x ~30W = 90W
(average rated = 22.5W/bar



Light and Power

Case	(1) Average Power (kW)	(2) Luminance cd/m^2	(3) Illuminance (fc)
T8 Fluorescent - Base Case	9.6	163	78
LED Light Bar - Test Case	4.5	136	45
Test Case as a % of Base Case:	47%	83%	58%
% Reduction	53%	17%	42%

(1) Power input for set of test cases.
(2) Luminance (brightness) as measured for two doors (average).
(3) Illuminance (light levels) measured for two doors (average)

Efficacy (Based on Measured Data)

Case	(4) Power Input (W per unit)	(5) Initial Lumens (lm/unit)	(6) Efficacy (lm/W)
T8 Fluorescent, (1) 5' lamp	44.4	3,750	84.4
LED Light Bar, average (*)	20.8	684	32.8
Test Case as a % of Base Case:	47%		39%

Efficacy (Based on Rated Data)

Case	(7) Power Input (W per unit)	(8) Initial Lumens (lm/unit)	(9) Efficacy (lm/W)
T8 Fluorescent, (1) 5' lamp	40.0	3,750	93.8
LED Light Bar, average (*)	22.5	1,026	45.6
Test Case as a % of Base Case:	56%		49%

 Phone: 415.434.2600

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Efficacy Summary

Summary of Findings

The new system provided a greater reduction in power than in illuminace even though the measured efficacy of the test case system (33 lm/W) is lower than the existing case.(84 lm/W) An analysis of this finding is provided in the project write up.

NOTES

* The project consists of installing an equal number of two types of LED bars, 228 LED bars that are installed in the center door mullions to replace two fluorescent lamps, and 114 LED bars that are installed on the sides of doors where there is only one fluorescent lamp. The initial lumens and rated power for "average" LED bar are used for comparison purposes to the base case.

(4) Power inputs based on measured data.
(5) Initial lamp lumens from manufacturer product sheet for Sylvania F040 (rated, not measured).
(5) As measured per ITL 60172 at 4 lumens per LED. Presumed to be same LED type as installed.
(6) Calculated as noted: initial lumens / input wattage
(7) Fluorescent systems based on nominal 80W rating for 2L ballast per technical service, Anthony.
(7) LED power input = per manufacturer, LEDPower (15W per 114 LED bar; 30W per 228 LED bar).
(8) Rating for LEDs was provided by the LED manufacturer to LEDPower based on raw testing at 3.6V forward voltage, @6 lumens per LED, yielding 684 lumens for the 114 LED bar and 1368 lumens for the 228 LED light bar. The average case per door is represented.
(9) Calculated as noted: initial lumens / input wattage

 Phone: 415.434.2600

Figure 6.2: Average Luminance Results: Butter & Eggs

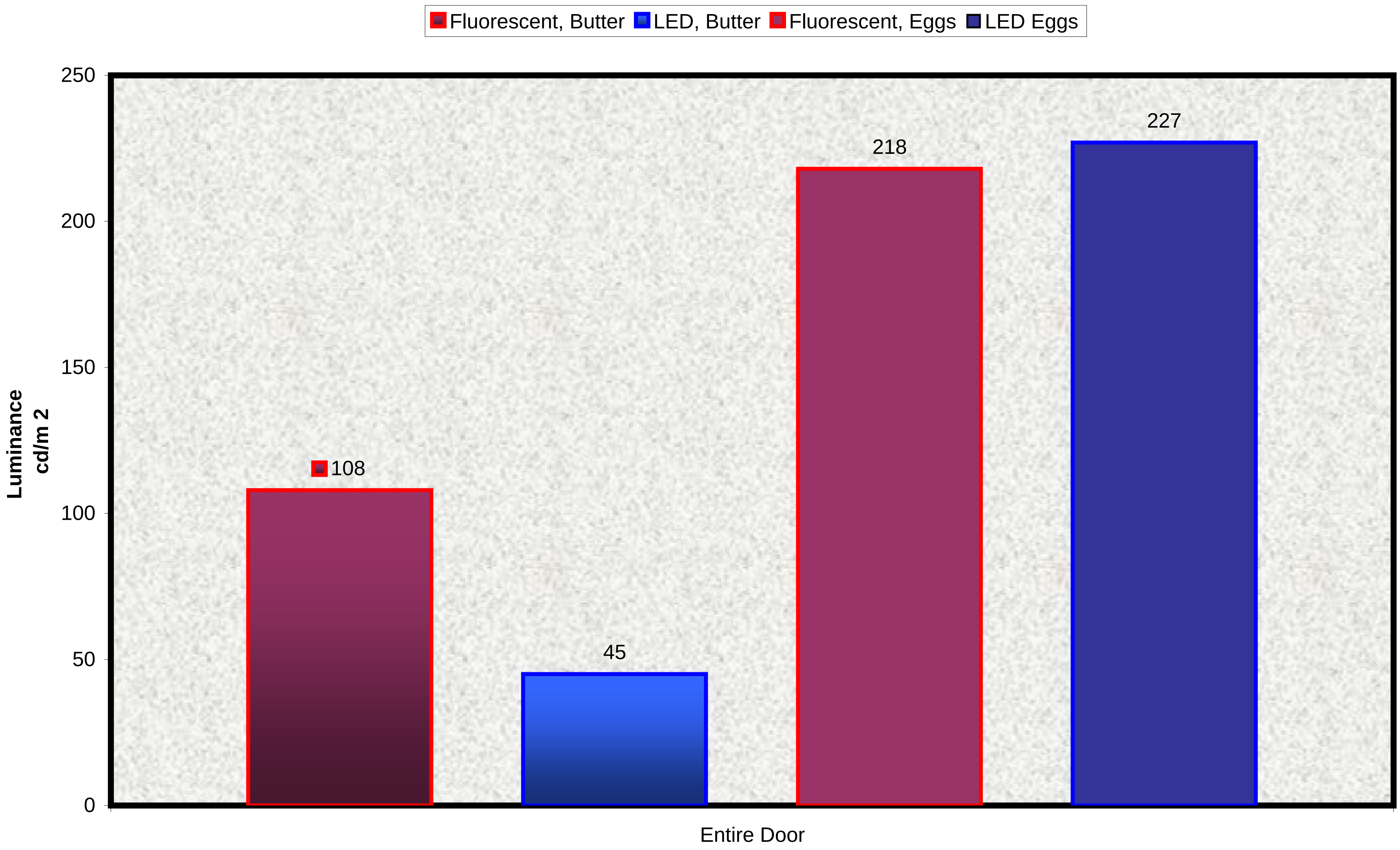


Figure 6.3: Max to Min Luminances - Butter

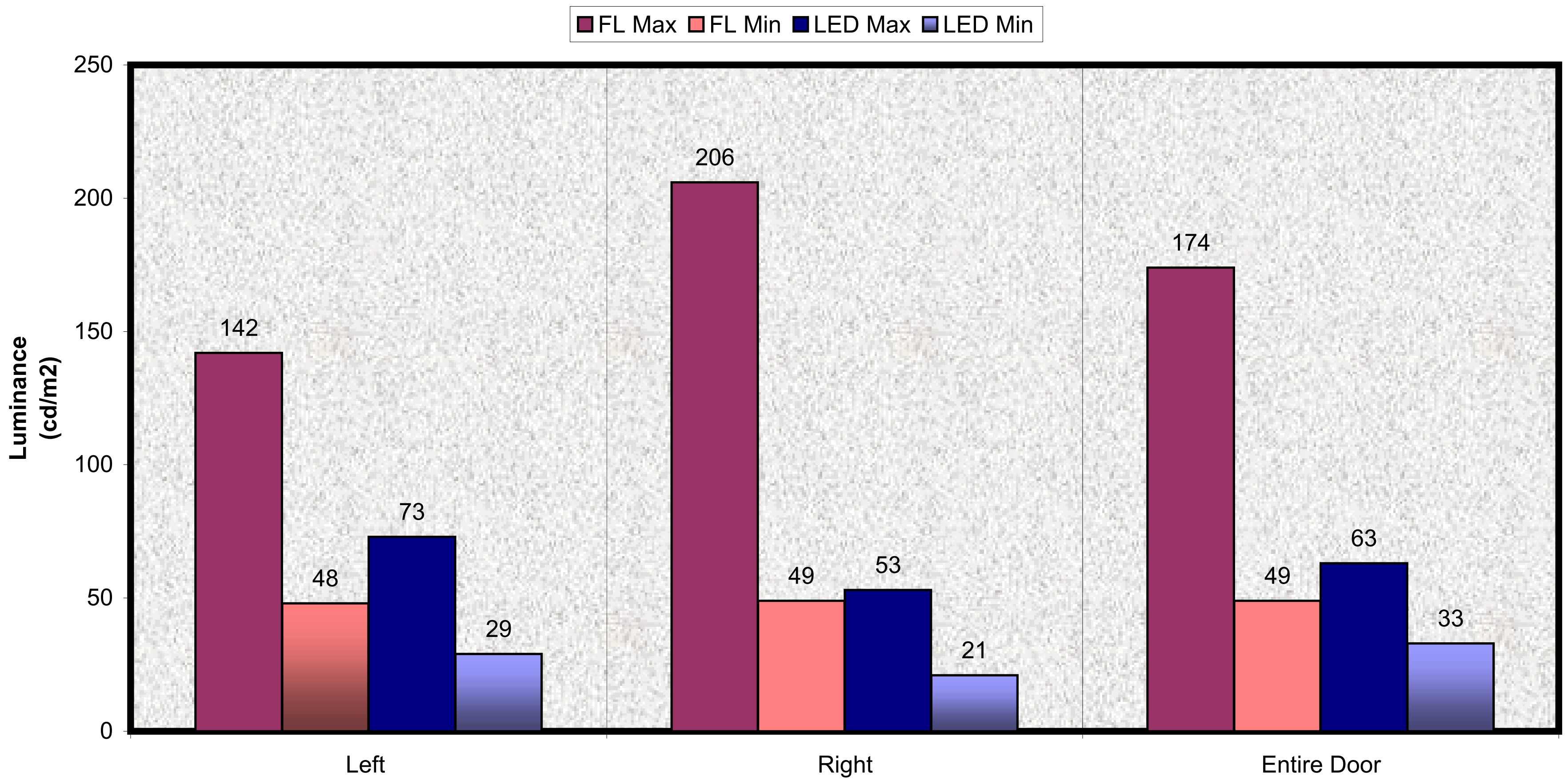


Figure 6.4: Max to Min Luminances - Eggs

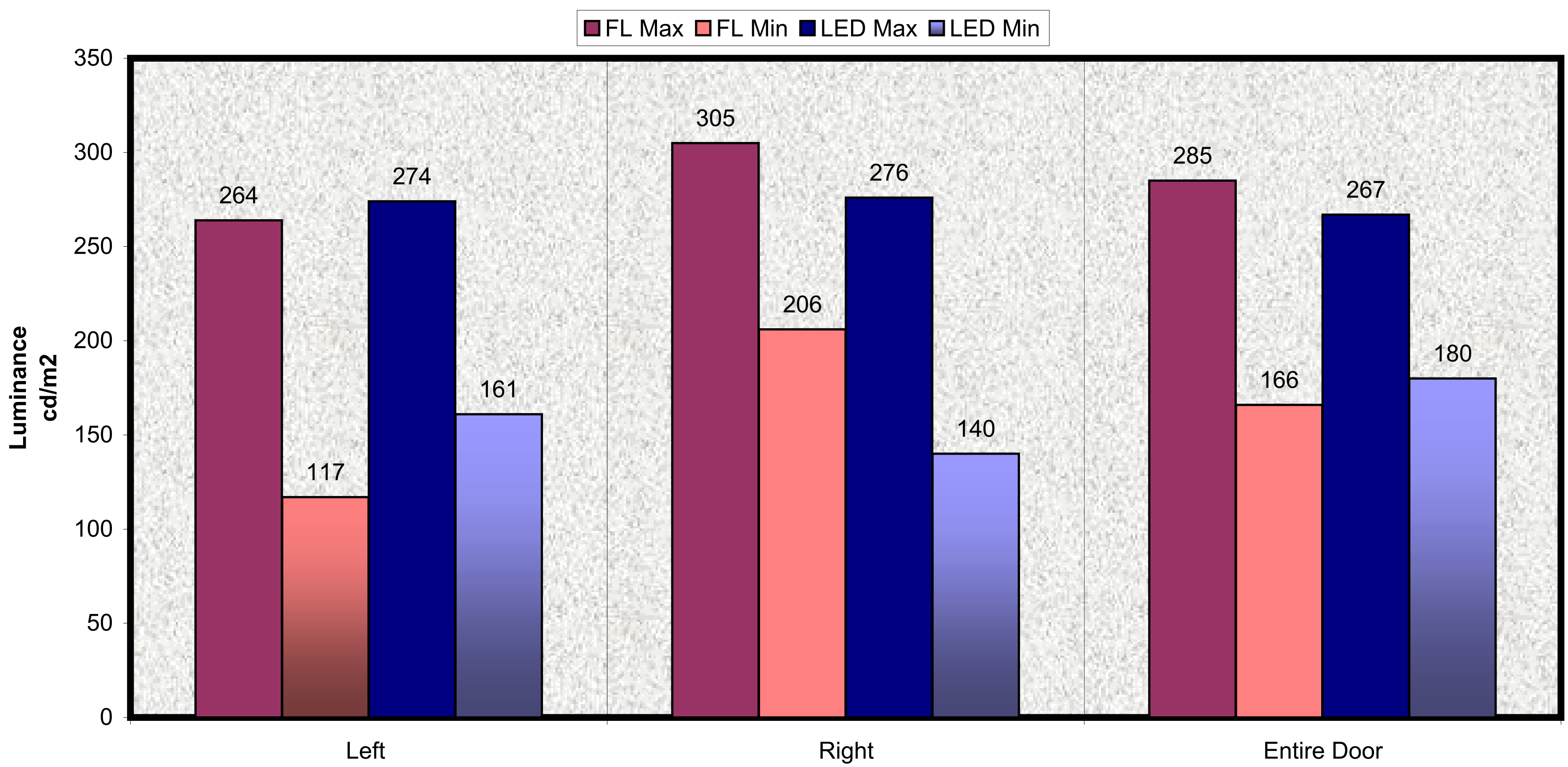
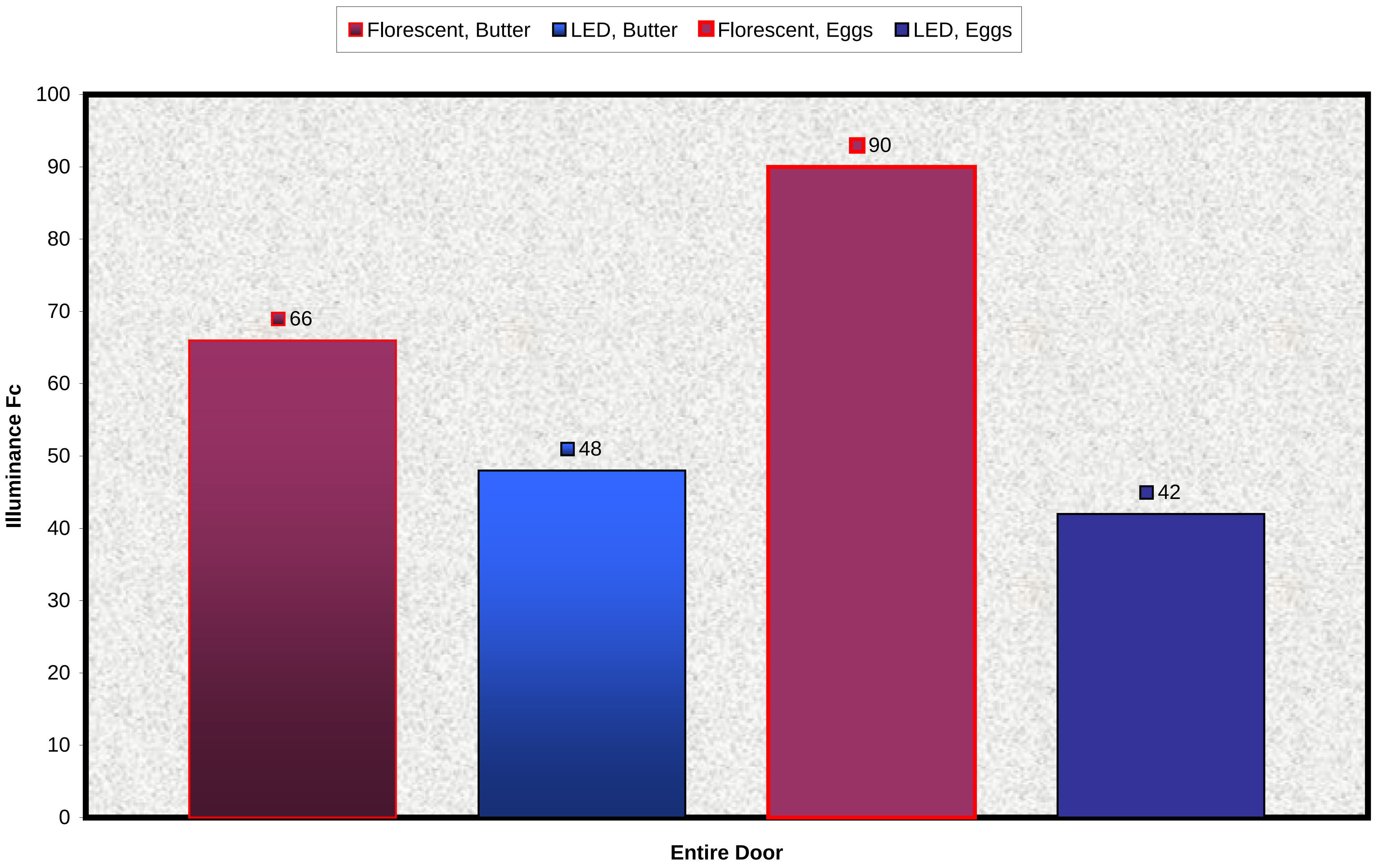


Figure 6.5: Average Illuminance Results: Butter and Eggs

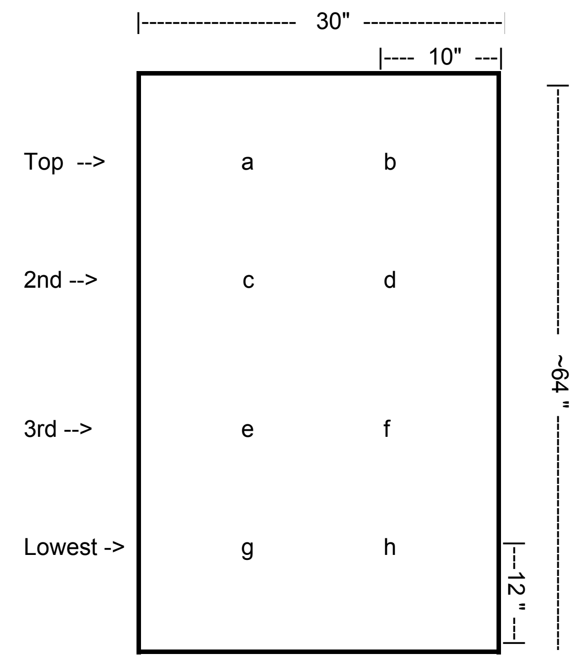


PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Grocery Store (San Francisco Bay Area)

Luminance results (cd/m^2)

		Fluorescent			LED		
	Position	Left	Right	Entire Door	Left	Right	Entire Door
Butter	Top	142	206	174	73	53	63
	2nd	84	178	131	29	37	33
	3rd	81	75	78	65	25	45
	Lowest	48	49	49	59	21	40
	Max:	142	206	174	73	53	63
	Min:	48	49	49	29	21	33
	Average:	**89**	**127**	**108**	**57**	**34**	**45**
	Max/Min:	3.0	4.2	3.6	2.5	2.5	1.9
Eggs	Position	Left	Right	Entire Door	Left	Right	Entire Door
	Top	264	305	285	219	140	180
	2nd	117	291	204	262	220	241
	3rd	217	217	217	274	260	267
	Lowest	126	206	166	161	276	219
	Max:	264	305	285	274	276	267
	Min:	117	206	166	161	140	180
	Average:	**181**	**255**	**218**	**229**	**224**	**227**
	Max/Min:	2.3	1.5	1.7	1.7	2.0	1.5

Data Set	Average:	**135**	**191**	**163**	**143**	**129**	**136**
	Max/Min:	2.5	2.0	**2.1**	1.8	2.0	**1.5**



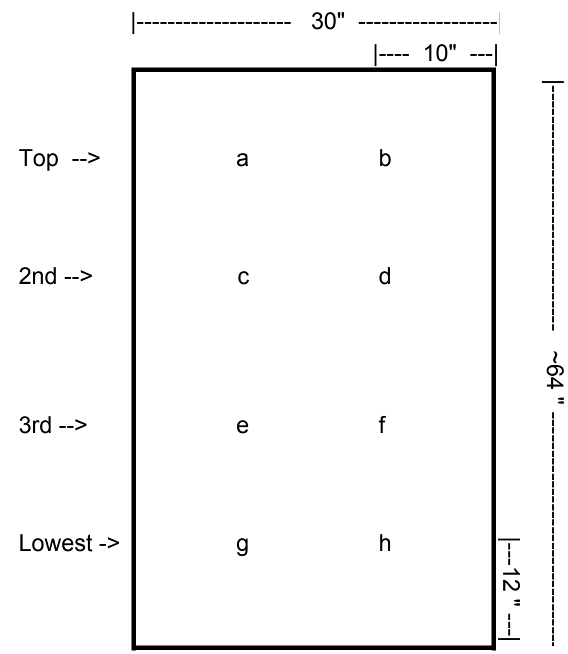
Door Measurement Positions

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Grocery Store (San Francisco Bay Area)

Illuminance Results (fc)

		Fluorescent			LED		
	Position	Left	Right	Entire Door	Left	Right	Entire Door
Butter	Top	59	87	73	63	63	63
	2nd	59	78	69	23	38	31
	3rd	58	60	59	26	57	42
	Lowest	59	64	62	45	62	54
	Max:	59	87	73	63	63	63
	Min:	58	60	59	23	38	31
	Average:	**59**	**72**	**66**	**39**	**55**	**48**
	Max/Min:	1.0	1.5	1.2	2.7	1.7	2.0
Eggs	Position	Left	Right	Entire Door	Left	Right	Entire Door
	Top	83	101	92	18	41	30
	2nd	81	89	85	34	62	48
	3rd	78	114	96	28	52	40
	Lowest	81	95	88	23	77	50
	Max:	83	114	96	34	77	50
	Min:	78	89	85	18	41	30
	Average:	**81**	**100**	**90**	**26**	**58**	**42**
	Max/Min:	1.1	1.3	1.1	1.9	1.9	1.7

Data Set	Average:	**70**	**86**	**78**	**33**	**57**	**45**
	Max/Min:	1.0	1.3	**1.2**	2.4	1.8	**1.9**



Door Measurement Positions

Appendix C-2
Project Savings and Economics

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Grocery Store (San Francisco Bay Area)
Cost Summary and Payback

Current Market

	LED Bars:	Notes:
Quantity:	216	for a 162-door installation
$/Door	$ 265.67	Backed out from total material
Material Cost:	$ 43,038.00	per "Energy Solutions", project cost estimate
	Labor:	
Cost/door	$ 58.00	T. Zaremba estimate, Contractor, 3/20/08
# of Doors	162	
Labor Cost:	$ 9,396.00	
Total Cost:	$52,434.00	

Mature Market

	LED Bars:	Notes:
Quantity:	216	
$/Door	$ 225.82	
Material Cost:	$ 36,582.30	per Cary Alberg, mature market might reduce cost by 15%
	Labor:	
Cost/door	$ 30.00	LEDPower cost estimate per Cary Alberg, 2/26/08
# of Doors	162	
Labor Cost:	$ 4,860.00	
Total Cost:	$41,442.30	

Project Payback Summary

The simple payback periods shown below indicate the anticipated cost and savings for current market and mature market conditions respectively, where increased sales volume and production will permit material cost reductions to the end user. The "payback period with avoided cost" scenarios include additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

Annual Energy Savings	Simple Payback Period, Current Market	Annual Energy Savings	Simple Payback Period, Mature Market
$ 4,160.64 /yr	**12.6 years**	$ 4,160.64 /yr	**10 years**
Total Annual Savings	**Payback Period w/Avoided Cost, Current Market**	**Annual Savings**	**Payback Period w/Avoided Cost, Mature Market**
$ 5,383.70 /yr	**9.7 years**	$ 5,383.70 /yr	**7.7 years**

LIFE CYCLE COST ANALYSIS

Useful Life:	50,000	hrs
Operation	4,171	hrs/yr
Expected Life	12.0	yrs, based on annual operation over useful life.
Project Payback	12.6	yrs (beased on energy alone, current market conditions)

Phone: 415.434.2600

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Costco Store (Concord)
Energy Savings

The calculated savings is based on replacing (216) fluorescent lamps and associated ballasts with (216) LED bars in (2) walk-in freezer cases [i.e., (108) doors, (144) fixtures] and in (1) walk-in cooler case [i.e., (54) doors, (72) fixtures]. The "average power" data is extrapolated from (3) metered circuits [i.e., (1) circuit for each freezer and cooler] consisting of the lighting sources that serve these cases, metered circuits included (9) doors, (12) fixtures for the freezers and (12) doors, (16) fixtures for the cooler.

Lighting Retrofit Energy Savings

	(1) Lighting Annual Hours	(2) Average Measured Power (kW)	(3) Lighting Energy (kWh/yr)	% reduction in kWh from base case	Average Meas. W /3-door set	Average Meas. W / door
T8 Fluorescent	4,171	9.6	40,042		177.8	59.3
LED Light Bar	4,171	4.5	18,770		83.3	27.8
		5.1	21,272	47%		

Electric Demand Savings: 5.1 kW
Electric Energy Savings: 21,272 kWh/yr

LowTemp Heat Calculations (2 Freezer Cases)

	(2) Average Power (kW)	(4) Power to Light Source (%)	(5) Power to Heat (%)	(6) Heat Load Source (kW)
T8 Fluorescent	6.5	90%	79%	4.6
LED Light Bar	3.0	86%	79%	2.0
				2.6

Compressor Efficiency: 1.4 COP (7)
Heat Load Reduction: 2.6 kW
Case Lighting Operating Hours: 4,171 hrs/yr (1)

Compressor kW Savings: 1.9 kW (8)
Compressor Energy Savings: 7,925 kWh/yr (3)

MedTemp Heat Calculations (1 Cooler Case)

	(2) Average Power (kW)	(4) Power to Light Source (%)	(5) Power to Heat (%)	(6) Heat Load Source (kW)
T8 Fluorescent	3.1	90%	79%	2.2
LED Light Bar	1.5	86%	79%	1.0
				1.2

Compressor Efficiency: 2.5 COP (7)
Heat Load Reduction: 1.2 kW
Case Lighting Operating Hours: 4,171 hrs/yr (1)

Compressor kW Savings: 0.5 kW (8)
Compressor Energy Savings: 2,086 kWh/yr (3)

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Costco Store (Concord)
Energy Savings

Energy Savings Summary

Lighting Demand Savings:	**5.1 kW**	
Lighting Energy Savings:	**21,272 kWh/yr**	
Compressor Demand Savings:	**2.4 kW**	
Compressor Energy Savings:	**10,011 kWh/yr**	
Total Demand Savings:	**7.5 kW**	
Total Energy Savings:	**31,283 kWh/yr**	
Energy Rate:	**$ 0.1330 /kWh**	per Time of Use rate during savings period, E-19S
Annual Dollar Savings, Energy:	**$ 4,160.64 /yr.**	

This compressor analysis is *limited to the differential cooling load imposed by the lighting system, not the total cooling load* of a particular display case or walk-in box. The differential compressor power requirements are based on calculated cooling load and energy-efficiency ratios (EER) obtained from manufacturers' data.

EER is determined using the attached Compressor efficiency calculations. The saturated condensing temperature (SCT) is determined using the following equations:

For medium temperature (MT): $SCT=DB_{adj}+15$

For low temperature (LT): $SCT=DB_{adj}+10$

where Dbadj = dry-bulb temperature (F) of ambient or adjacent space where the compressor/condensing units reside. Defaults are base on climate zone design values as follows:

Zone	Description	DB_{adj}
12	Central Valley - Sacramento	100

Notes:

1) Annual operating hours of the refrigeration case lighting system is 80 hrs/wk * 52.14 wks/yr = 4171 hrs/yr. This operating schedule is supported by the power data taken before and after LED installation.
2) Average demand extrapolated from power logging data.
3) Energy Savings (kWh/yr) = Demand Savings (kW) * Annual Operating Hours (hrs/yr)
4) Power to Light Source (%) = Rated Lamp Ouput Power / Input Power.
5) Power to Heat = (79%) lamp energy per IES Handbook 9th Edition, pg 6-29 and also per "Energy-Efficient Lighting Alternative for Commercial Refrigeration", Narendran/Brons/Taylor, November 16, 2006 [RPI Lighting Research Center], also IES 9th Edition Section 6
6) as calculated: total measured load to heat, elminating ballast/driver energy and visible light
7) Refrigeration coefficient of performance (COP) calculated from EER (COP=EER/3.412).
8) Electric demand savings for refrigeration is based on average COP (see note 7).

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Display Case LED Lighting **Compressor Efficiency Calculations**

This calculation was prepared using available manufacturer's data for typical Copeland and Carlyle refrigeration compressors using typical performance criteria. Please see accompanying charts for a comparison of the results of this methodology with the results provided by SCE.

Copeland Reciprocating Compressor Performance (Refrigerant # 404A)

Very close to the ARI standard EER of 6.41 at -25F dewpoint

Very close to the ARI standard EER of 12.59 for 20F dewpoint temp.

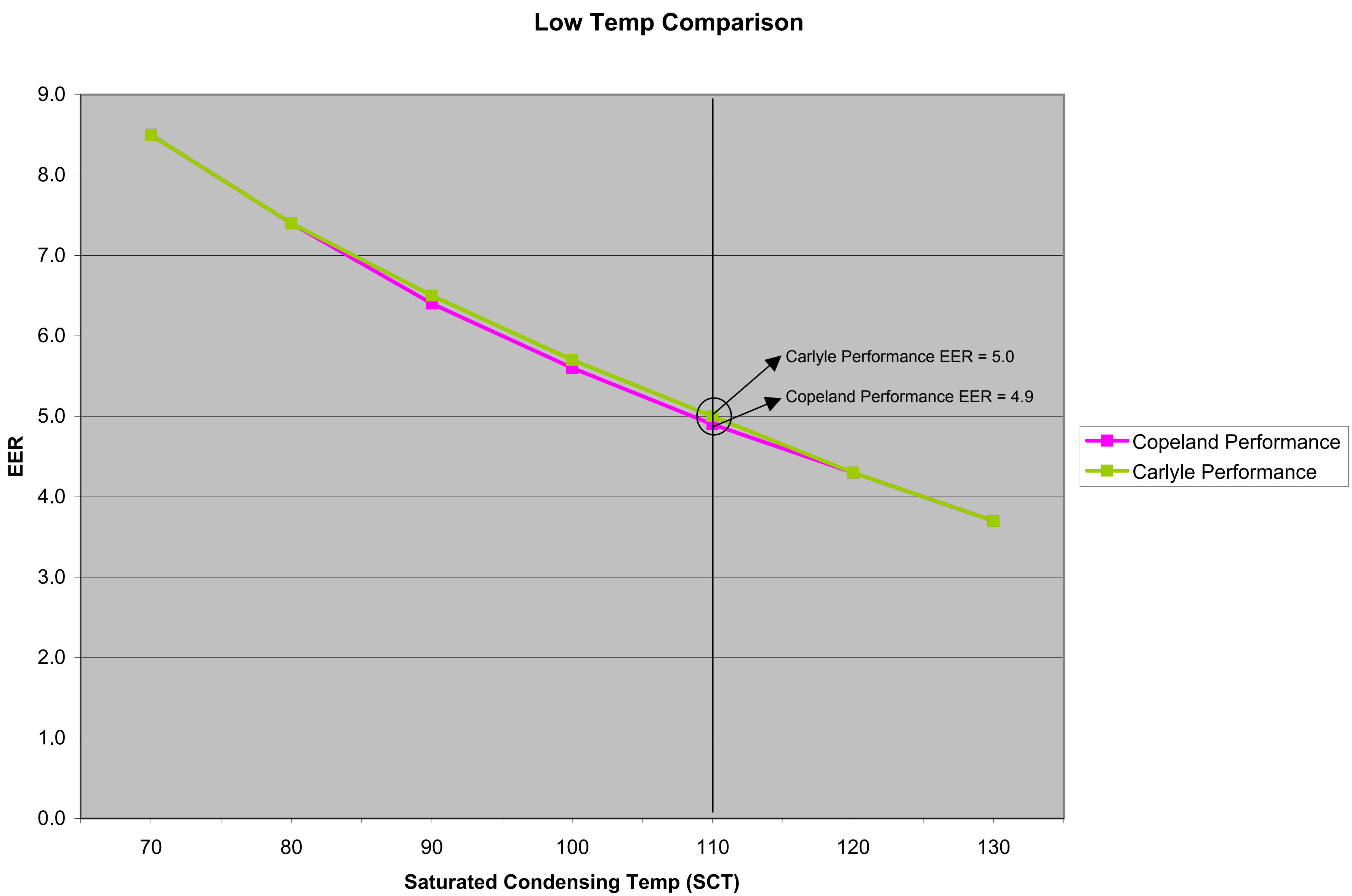
SCT	Low Temp EER (1)	Medium Temp EER (2)
70	8.5	17.8
80	7.4	14.9
90	6.4	12.6
100	5.6	10.7
110	4.9	9.1
120	4.3	7.7
130	3.7	6.5

Assumptions:
1) The low temp EER based on a typical 10 hp, Copeland Discus reciprocating semi hermetic compressor (model # 4DA3-100E). The compressor performance is at -25F SST.
2) The medium temp EER based on a typical 10 hp, Copeland Discus reciprocating semi hermetic compressor (model #3DB3-100E). The compressor performance is at +20F SST.

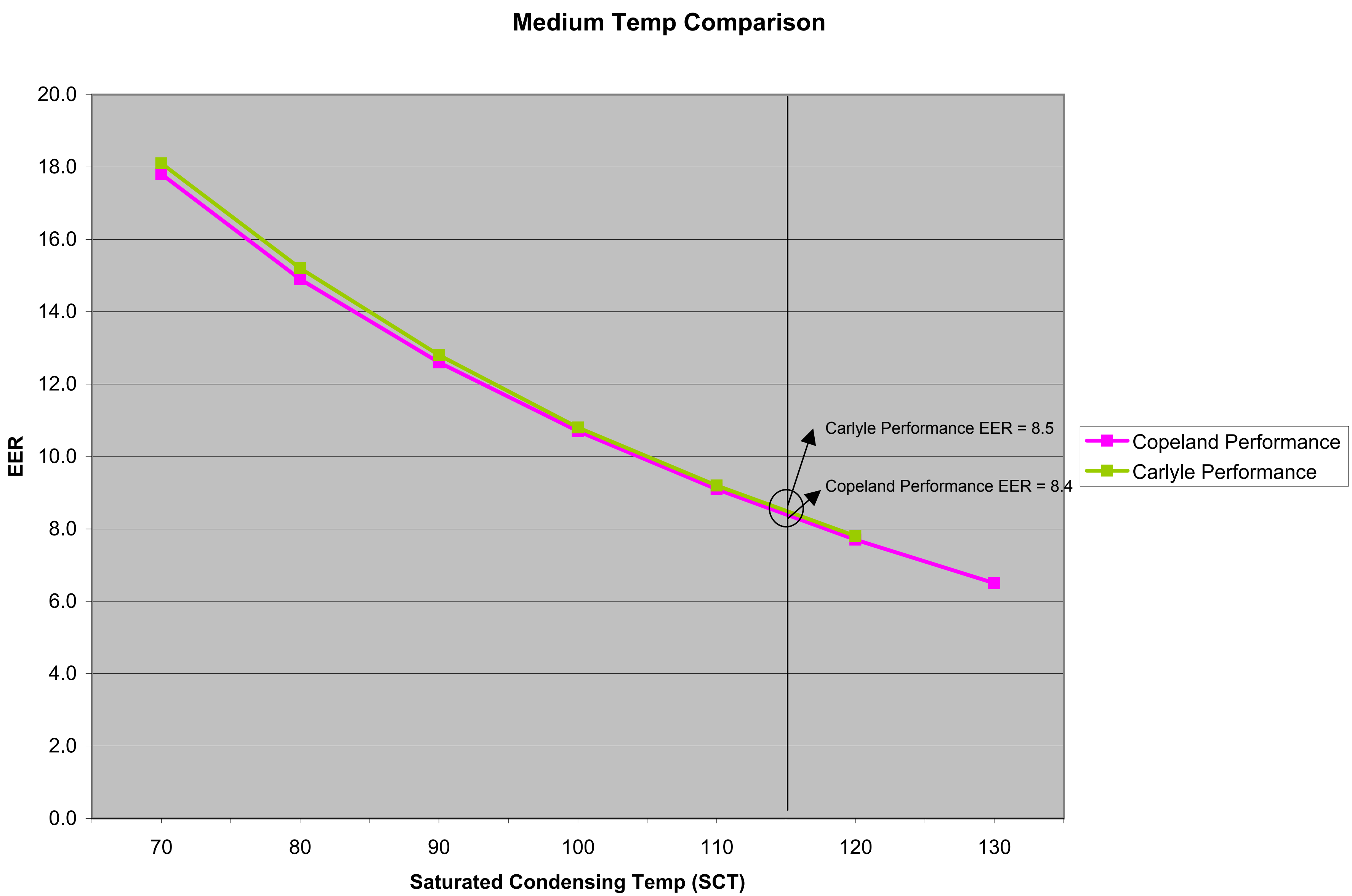
Carlyle Reciprocating Compressor Performance (Refrigerant # 404A)

SCT	Low Temp EER (1)	Medium Temp EER (2)
70	8.5	18.1
80	7.4	15.2
90	6.5	12.8
100	5.7	10.8
110	5	9.2
120	4.3	7.8
130	3.7	

Assumptions
1) The low temp EER based on a typical 10 hp, Carlyle 06DR337 reciprocating semi hermetic low temp compressor. The compressor performance is at -25F SST.
2) The medium temp EER based on a typical 10 hp, Carlyle 06DR337 reciprocating semi hermetic medium temp compressor. The compressor performance is at +20F SST.



Low Temp Comparison
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
EER
70
80
90
100
110
120
130
Saturated Condensing Temp (SCT)
Carlyle Performance EER = 5.0
Copeland Performance EER = 4.9
Copeland Performance
Carlyle Performance


Medium Temp Comparison
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
EER
70
80
90
100
110
120
130
Saturated Condensing Temp (SCT)
Carlyle Performance EER = 8.5
Copeland Performance EER = 8.4
Copeland Performance
Carlyle Performance

INITIAL MAINTENANCE SAVINGS FOR REPLACEMENT OF FLUORESCENT SOURCES WITH LED CASE LIGHTS

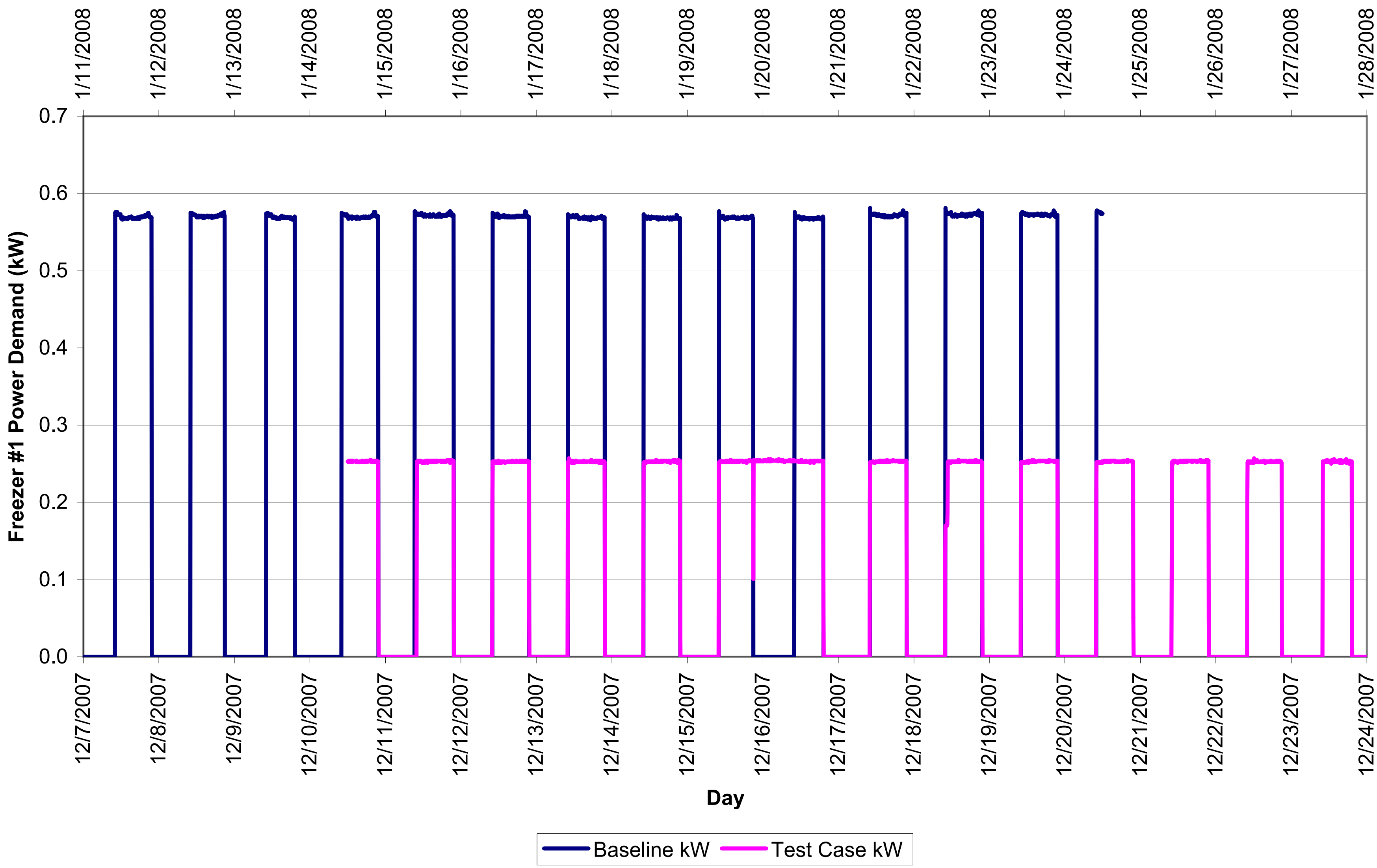
Replacement of existing fluorescent systems with new LED systems will typically result in avoided maintenance costs over the life of the new LED system because the project replaces used capital equipment. Based on average life characteristics of the current and proposed equipment, more than 2 cycles of lamp replacement will be avoided during the expected life of the LED system. During that period, it is predicted that a small percentage of ballasts will fail based on the calculated annual failure rate; actual failures will likely be higher or lower depending on the age of the existing ballasts. The overall avoided maintenance costs during the expected life of the LED system are calculated below.

Item	Equipment	Type	Expected Life (hrs) (1)	Annual Failure Rate (2)	Unit Labor Hrs (3)	Unit Labor Cost (4)	Unit Material Cost (5)	Unit Replacement cost	Total Replacement Cost/door (6)	Total replacements in LED life	Cost per LED life cycle	Annualized Cost (per door)	Total Net Annualized Savings
a	FO40/835/XP/ECO	Lamp	24,000	17.4%	0.089	$ 8.35	$ 4.49	$ 12.84	$ 17.08	2.08	$ 35.58	$ 2.97	
b	Anthony LT2X40/120	ballast	140,160	3.0%	0.851	$ 79.85	$ 149.95	$ 229.80	$ 153.97	0.36	$ 54.93	$ 4.58	
	TOTAL FLUORESCENT:										**$ 90.50**	**$ 7.55**	
c	LED light bar/door	unit	50,000	8.3%	0.000	$ -	$ -	$ -	$ -	1.00	**$ -**	**$ -**	

INITIAL MAINTENANCE SAVINGS, NET ANNUAL SAVINGS FOR LED (PER DOOR) **$ 7.55** **$ 1,223.06**

(1) Assume Rated lamp life at 3 Hrs/Start per industry standard rating; ballast and LED system life of 50,000 hours per manufacturer.
(2) Annual failure rate = Annual operating hours / expected life. Assume operating hours to be: 4,171 /yr as calculated for this case study.
(3) Labor hours per Means Electrical for fluorescent lighting maintenance activities (spot relamp/reballast); LED system estimate per area contractor.
(4) Assume Labor Rate at $ 93.83 /hr. (Means Electrical 2007 for Electrician; City modifier Oakland, CA.)
(5) Materials cost for existing per on-line ordering, www.bulbs.com (lamp), www.atlantalightbulbs.com (ballast).
(6) For fluorescent system, total cost per door is based on 216 existing lamps per 162 doors and one fluorescent ballast per two lamps (108 ballasts per 162 doors).

Measured Power Freezer #1, Fluorescent vs. LED



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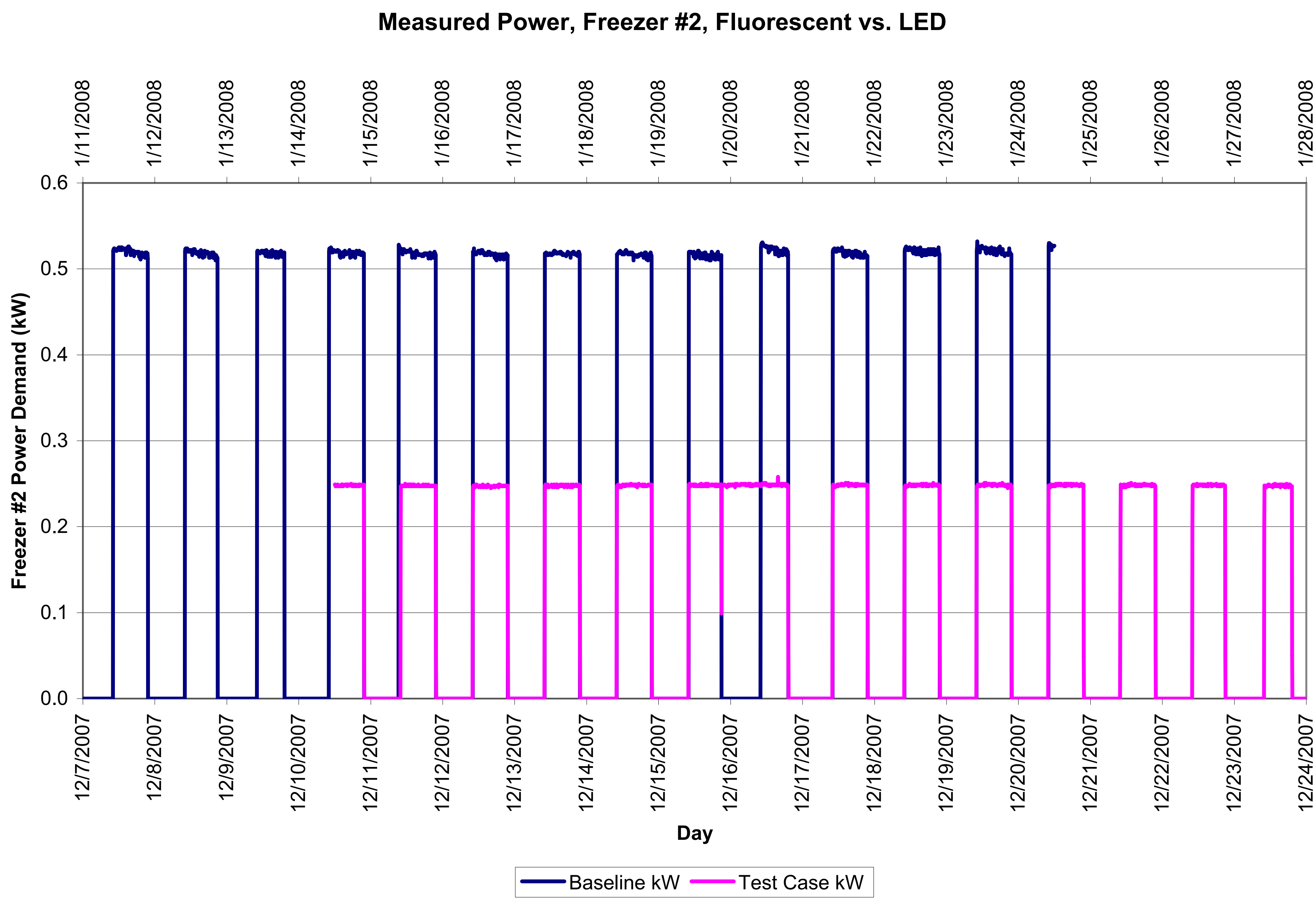

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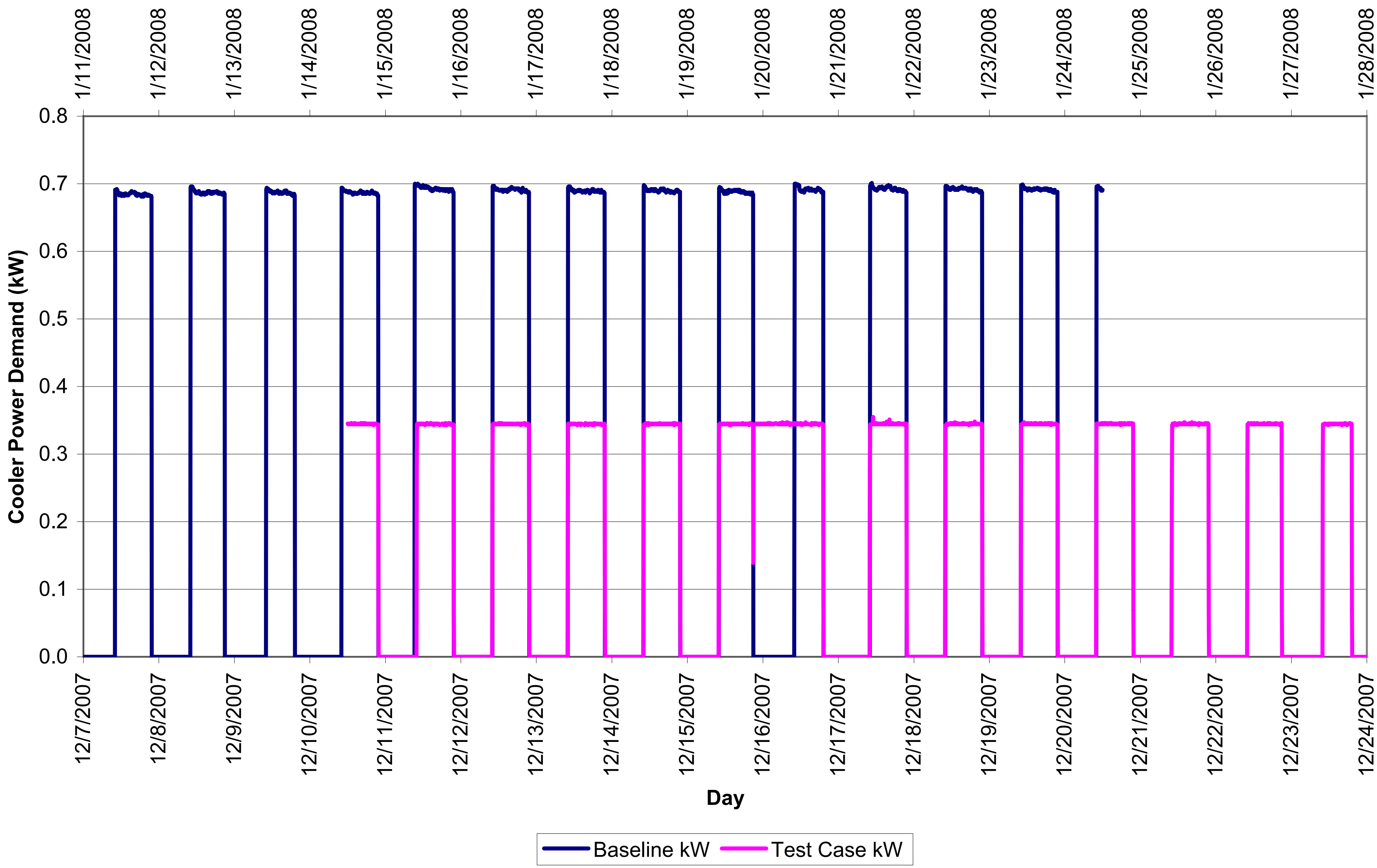
Measured Power, Cooler, Fluorescent vs. LED



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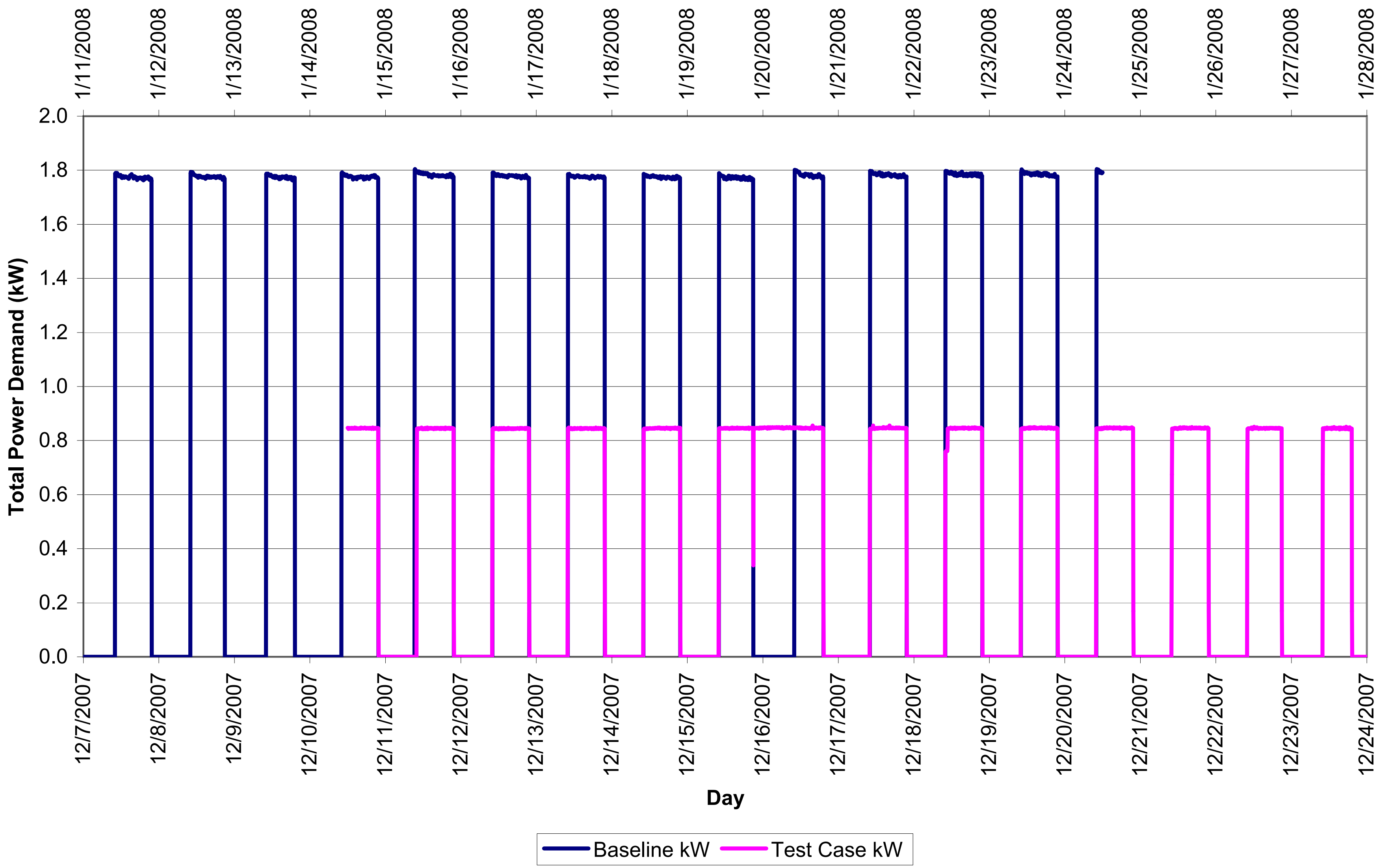
Measured Power, Total, Fluorescent vs. LED



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Project: **ELECTRICITY RATE ANALYSIS**
Customer: PG&E
Facility: Costco
Building: Concord

Utility: PG&E
Rate Schedule E-19S
Effective Date: 3/1/08

Background

This sheet summarizes the energy and demand charges during summer and winter for peak, partial-peak, and off-peak periods for time-of-us rate schedules.

Approach

The user enters the appropriate utility period definitions and rates on this sheet. Average electric rates are calculated for various use profiles (the following sheets.

Assumptions

Holidays as defined in this rate schedule are assigned to the legally observed dates. When a billing month includes both summer and wint days, demand charges are calculated by prorating separately calculated winter and summer demand charges by the appropriate number of da in each season during the billing period. This spreadsheet does not calculate this proration; billing periods are assumed to coincide with seas changeover dates. This spreadsheet does not include customer charges or state and local taxes. The calculations assume peak and maximu demand are concurrent.

Analysis

UTILITY PERIOD DEFINITIONS

SUMMER May 1-October 31 6 months

PERIOD DEFINITIONS						BREAKDOWN			SUMMARY BY PERIOD		
period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
peak	1200	to	1800	5	M/F	6	26.07	782	782		
partial-peak	830	to	1200	5	M/F	3.5	26.07	456		456	
	1800	to	2130	5	M/F	3.5	26.07	456		456	
off-peak	2130	to	830	5	M/F	11	26.07	1,434			1,434
	-	to	2400	2	S/S	24	26.07	1,251			1,251
Weekday holidays which are completely off-peak						(	3)		(18)	(21)	39

WINTER Nov 1-April 30 6 months

PERIOD DEFINITIONS						BREAKDOWN					
period	daily hours			days per week		hr/day	wk/yr	hr/yr			
peak	-	to	-	5	M/F	0	26.07	0	0		
partial-peak	830	to	2130	5	M/F	13	26.07	1,695		1,695	
	-	to	-	5	M/F	0	26.07	0		0	
off-peak	2130	to	830	5	M/F	11	26.07	1,434			1,434
	-	to	2400	2	S/S	24	26.07	1,251			1,251
Weekday holidays which are completely off-peak:						(	5)		0	(65)	65
								TOTAL ==>	764	2,521	5,474
								% total	8.7%	28.8%	62.5%

UTILITY RATE STRUCTURE (Non-FTA)

		ENERGY	DEMAND	
		$/kWh	$/kW peak	$/kW max
SUMMER:	May 1-October 31			
	peak	0.13458	11.59	6.89
	partial-peak	0.09257	2.65	
	off-peak	0.07541	0.00	
WINTER:	Nov 1-April 30			
	peak	0.00000	0.00	
	partial-peak	0.08256	1.00	6.89
	off-peak	0.07286	0.00	

Project: ELECTRICITY RATE ANALYSIS
Customer: PG&E
Facility: Costco
Building: Concord

Utility: PG&E
Rate Schedule E-19S
Effective Date: 3/1/08

Background
This worksheet calculates the marginal cost of electricity with and without demand, for a particular operating use profile.

Approach
This sheet calculates the number of hours per year a given building operates during peak, partial-peak, and off-peak periods. It then uses the data from the TOU Utility Definitions tab to calculate the marginal cost of electricity.

Assumptions
Holidays as defined in this rate schedule are assigned to the legally observed dates. When a billing month includes both summer and winter days, demand charges are calculated by prorating separately calculated winter and summer demand charges by the appropriate number of days in each season during the billing period. This spreadsheet does not calculate this proration; billing periods are assumed to coincide with season changeover dates. This spreadsheet does not include customer charges or state and local taxes. The calculations assume peak and maximum demand are concurrent.

Analysis

TIME PERIOD: **Refrigerated case lighting operating hours**

OCCURRENCE OF PROJECT SAVINGS: **Approximately 10 am until 10 pm, M-F; 10 am 9:00 pm, Saturday; 10 am - 7:00 pm Sunday**

SUMMER May 1-October 31 6 months

period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
	SCHEDULE					SAVINGS SCHEDULE			SUMMARY BY PERIOD		
peak	1200	to	1800	5	M/F	6.0	26.07	782	782		
partial-peak	830	to	1200	5	M/F	2.0	26.07	261		261	
	1800	to	2130	5	M/F	3.5	26.07	456		456	
off-peak	2130	to	830	5	M/F	0.5	26.07	65			65
	-	to	2400	2	S/S	10.0	26.07	521			521
Weekday holidays which are completely off-peak:						(	3)		(18)	(17)	35

WINTER Nov 1-April 30 6 months

period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
	SCHEDULE					SAVINGS SCHEDULE					
peak	-	to	-	5	M/F	0.0	26.07	0	0.0		
partial-peak	830	to	2130	5	M/F	11.5	26.07	1,499		1,499.0	
	-	to	-	5	M/F	0.0	26.07	0		0.0	
off-peak	2130	to	830	5	M/F	0.5	26.07	65			65.2
	-	to	2400	2	S/S	10.0	26.07	521			521.4
Weekday holidays which are completely off-peak:						(	5)		0.0	(57.5)	57.5
								TOTAL ==>	764.1	2141.9	1265.2
								% total	18.3%	51.3%	30.3%

PROJECT UTILITY RATE:
Energy Savings: 1 additional kW saved x 4,171 hrs/yr = 4,171 kWh/yr
Demand Savings: 1 kW per month

	ENERGY	DEMAND	
SUMMER period	$/kW	$/kW peak	$/kW max
peak	102.83	69.54	41.34
partial-peak	64.84	15.90	0.00
off-peak	46.84	0.00	0.00
subtotal	214.51	85.44	41.34
WINTER period			
peak	0.00	0.00	0.00
partial-peak	119.01	6.00	41.34
off-peak	46.93	0.00	0.00
subtotal	165.94	6.00	41.34

AVERAGE RATE CALCULATION

$380.45 /yr avoided energy charges
$91.44 /yr avoided time-related demand charges
$82.68 /yr avoided nontime-related demand charges
$554.57 /yr

$0.1330 /kWh average annual electric rate INCLUDING demand *
$0.0912 /kWh average annual elec rate NOT INCLUDING demand

* correct project rate for load reducing project includes demand

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Costco Store (Concord) vs. Northern California Grocery Store

A prior study was conducted for PG&E Emerging Technologies, "Application Assessment Report #0608 LED Supermarket Case Lighting Grocery Store, Northern California". A comparison of key results is made in the table below. Values from the "Northern California Grocery Store" case were drawn from the prior study, while the COSTCO results are reported elsewhere in this report.

NORTHERN CALIFORNIA GROCERY STORE (previous study):

The calculated savings is based on replacing (36) fluorescent lamps and associated ballasts with (60) LED bars in (6) freezer cases [i.e., (1) aisle, (30) doors]. The "average power" data represents an entire metered circuit consisting of the lighting sources that serve these cases.

Lighting Retrofit Energy Savings

	Case Lighting Annual Hours (hrs/yr)	Average Power (kW)	Lighting Energy (kWh/yr)	Average Meas. W / door	% reduction in kW from base case	Illuminance (fc)	% reduction in fc from base case	% fc reduction / % kW reduction
T8 Fluorescent	6,205	2.25	13,986	75.1		186		
LED Light Bar	6,205	1.29	8,029	43.1		129		
		0.96	5,957		43%		31%	72%

COSTCO CONCORD LOCATION (this study):

The calculated savings is based on replacing (216) fluorescent lamps and associated ballasts with (216) LED bars in (2) walk-in freezer cases [i.e., (108) doors, (144) fixtures] and in (1) walk-in cooler case [i.e., (54) doors, (72) fixtures]. The "average power" data is extrapolated from (3) metered circuits [i.e., (1) circuit for each freezer and cooler] consisting of the lighting sources that serve these cases, metered circuits included (9) doors, (12) fixtures for the freezers and (12) doors, (16) fixtures for the cooler.

Lighting Retrofit Energy Savings

	Case Lighting Annual Hours (hrs/yr)	Average Measured Power (kW)	Lighting Energy (kWh/yr)	Average Meas. W / door	% reduction in kW from base case	Illuminance (fc)	% reduction in fc from base case	% fc reduction / % kW reduction
T8 Fluorescent	4,171	9.6	40,042	59.3		78		
LED Light Bar	4,171	4.5	18,770	27.8		45		
		5.1	21,272		53%		42%	80%

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Appendix D
Customer Feedback Survey

CUSTOMER FEEDBACK SURVEY – REFRIGERATED CASE LIGHTING TEST: COSTCO

DEPARTMENT/POSITION MANAGER DATE 3-26-08

NAME (Optional) MARK SOVEY

A change was recently made to some of the display lighting in two low temperature freezer cases and one medium temperature refrigerated case at the Concord location. Please fill out a separate survey form for each lighting system for which you are providing feedback. Please indicate the lighting system that you are currently evaluating by marking an "X" next to the corresponding Test Area:

X TEST AREA 1 or 2: Freezer Case	___ TEST AREA 3: Refrigerated Case

For the questions below, circle the response that most closely matches your answer. Ratings are from 1 to 10; 1 being the LOWEST score and 10 being the HIGHEST score. Comments are encouraged.

1. Did you notice the lighting change before this survey made you aware of it?

Did Not Notice — Noticed

1 2 3 4 5 6 7 8 9 (10)

2. Have you overheard or otherwise received any direct feedback from store customers about the lighting change?

Yes / (No)

Feedback: Negative / Neutral / Positive

3. In general, does the replacement lighting system create more or less visual interest in the merchandise than was provided by the previous lighting system?

Creates Less Visual Interest IN CONCLUSIVE Creates More Visual Interest

1 2 3 4 5 6 7 8 9 10

4. In general, does the replacement lighting system seem to provide more light, the same amount of light, or less light than was provided by the previous lighting system?

Provides Less Light — Same Amount — Provides More Light

1 2 3 4 (5) 6 7 8 9 10

5. In general, how satisfied are you with the replacement lighting system?

Not Satisfied — Very Satisfied

1 2 3 4 5 6 7 (8) 9 10

6. Would you recommend that the replacement lighting system be considered for use in additional display areas at this facility?

Would not recommend it would'nt know where else it could be used, Would recommend it

1 2 3 4 5 6 7 8 9 10

Comments: So Far...So Good