Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Report #0608

LED Supermarket Case Lighting
Grocery Store, Northern California

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PREFACE

Customer Energy Efficiency Program

EMCOR Energy Services, under contract to Pacific Gas & Electric (PG&E) Company, has conducted an Emerging Technology Project Report at a host customer site, which is a grocery store in Northern California. The purpose of this project is to assist PG&E with the evaluation of emerging technologies 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.

PG&E has a partnership with the California Lighting Technology Center (CLTC) at the University of California, Davis. As PG&E's lighting portfolio manager, CLTC provides targeted expertise related to efficient lighting technologies, and was involved in the early development, photometric testing, and lighting system performance evaluation associated with this project.

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 Manager is Jonathan Livingston, and the PG&E Emerging Technologies Lighting Portfolio Manager is Don Aumann, P.E., of the CLTC. The PG&E Project Manager for this project is Mary Matteson Bryan, P.E.

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ACKNOWLEDGMENTS

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1. EXECUTIVE SUMMARY

EES evaluated an emerging technology application that potentially provides lighting energy efficiency improvements. This technology was tested at a commercial grocery facility in northern California. In this demonstration project, light emitting diode (LED) source illumination was installed to replace T8 fluorescent lighting in a row of freezer cases. The project consisted of replacing (36) 5-foot F58T8 high-output fluorescent lamps and associated ballasts with (60) LED bars, each 4-feet in length.

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 power demand of the lighting case system by approximately 43%, with a commensurate reduction in luminance of 33%. The consistency of the lighting between cases was found to be more uniform with the LED system than with the fluorescent system. The results imply that the test-case LED lighting system is more efficient overall than the base case fluorescent system. Additional demand savings occurred because of the reduction in refrigeration use 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 from door to door than does the fluorescent system. The doors in some of the cases illuminated by fluorescent appear very dim, while others are quite bright. This observation is supported by the ratios of maximum to minimum luminance calculated from the measured data. Features related to color temperature and color quality were also measured. An expanded discussion of these findings is provided in Section 6.

The annual lighting energy savings of 5,957 kWh/yr for the demonstration project were calculated based on a continuous lighting demand reduction of 0.96 kW for the measured hours of operation (17 hours per day), extrapolated to calculate annual savings. Refrigeration system savings of 2,854 kWh/year were calculated based on a continuous reduction of average compressor demand. Total project savings are calculated to be 8,811 kWh/yr. The average costs of electricity and electrical demand were computed based on PG&E's E19S rate, typical for grocery stores; the monetary value of the annual energy savings was computed to be approximately $1,163 per year.

Replacement of fluorescent systems with new LED systems will 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 three 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 $375 annually over the life cycle of the LED source.

Table 1.1: Lighting System Performance

Case	Average Power	Luminance	Illuminance
T8 Fluorescent - Base Case	2.25 kW	134 cd/m^2	186 fc
LED Light Bar - Test Case	1.29 kW	90 cd/m^2	129 fc
Test Case as a % of Base Case:	57%	67%	69%
% Reduction	43%	33%	31%

Table 1.2: Lighting Quality Attributes

Lighting Quality Attribute	Fluorescent System	LED System
Max-min luminance ratio measured at center of doors, computed between all doors (variance)	3.3 to 1 (3.3:1)	1.7 to 1 (1.7:1)
Color Rendering Index (CRI)	62 – 85[a]	77.5 (measured)
Correlated Color Temperature (CCT)	3500K to 4100K (typical) 3208K (measured)	3543K (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 $7,739, resulting in a simple payback period of 6.7 years based on energy savings alone. The vendor of the product tested in this study, LED Power, foresees a reduction in product cost as the market for this application matures. Based on a mature market, the estimated cost for implementation is $6,738, with a simple payback period of 5.8 years. Including the impact of avoided maintenance costs, the project payback period improves to 5.0 years for the current case, and is projected to be 4.4 years in mature market conditions. See Table 1.3 for a summary of project savings and estimated economics.

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 6,205 hours per year, therefore, the application has a favorable life cycle cost based on current market conditions and energy savings alone.

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. For example, since completion of the monitoring for this study, a more efficient power supply has been identified for use with refrigerated case LED lighting systems than that evaluated in this study. These forces combined are expected to result in continued improvement in the economics of LED technologies.

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	5,957	0.96	inc.								
Refrigeration	2,854	0.46	inc.								
Total	8,811	1.42	$1,163	$375	$1,538	$7,739	6.7	5.0	$6,738	5.8	4.4

2. PROJECT BACKGROUND

2.1 LED Technology Overview

Light emitting diode (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 efficient 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.

As of this writing, publication is pending for a follow-on RPI study that will evaluate LED lighting performance and shopper's lighting preferences for grocery store freezer cases. Readers are encouraged to review the results of this pending study when it is released.

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 by 60% from peak values for some lamp types at sub-freezing temperatures.[2]

LED assemblies for use in refrigerated cases are currently available in the marketplace, however. Some systems, including General Electric's "Gelcore" and systems available from NuaLight of Ireland, are designed specifically for use to provide illumination in the low temperature, retail display case market. The products used in this demonstration were LED light bars manufactured by LED Power, and Advance Transformer's XITANIUM drivers, which are general purpose LED components suitable for use in low temperature settings. See Figure 2.1 for a photograph of this lighting system installed in a display case.

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 project.

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[1] Raghavan, Ramesh and Narendran, Nadarajah, 2002
[2] Illuminating Engineering Handbook, 9th Edition, Chapter 6, Figures 6-41 & 6-44

Figure 2.1: Installed LED Lighting System Detail

3. PROJECT OBJECTIVES

The 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 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 seeks to determine the applicability of the emerging technology to the refrigerated case environment.

Quantification of potential energy savings was a second goal. This study incorporates 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 seeks to identify further available savings due to reduced refrigeration load requirements.

4. EXPERIMENTAL DESIGN AND PROCEDURE

4.1 Background

Prior to this study, PG&E and CLTC 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 grocery store, 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. 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:

September 01, 2006	Grocery store had new fluorescent lamps installed in cases included in study.
September 04, 2006	Completion of photometric testing and power measurement protocols.
September 04, 2006	Installation of recording power meter logger on case lighting circuit. Spot metering of individual loads and circuits for baseline.
September 04, 2006	Perform baseline photometric testing.
September 14, 2006	Replacement of fluorescent sources with LED sources in test cases.
September 29, 2006	Disconnect recording power meter logger from case lighting circuit. Spot metering of individual loads and circuits for test-case.
September 29, 2006	Perform test-case photometric testing.
October 2006	Evaluate and analyze data.

4.2 Project Scope and Definition

With CLTC's and the host customer's assistance, PG&E identified a facility and set of freezer cases for testing. The test area consists of 30 freezer doors for 6 Hussman cases along a single row. Although there are several cases, the interior space is open along the entire row. The two 120 V electrical circuits measured in this study include an additional "endcap" freezer case, which did not have any changes made to the lighting systems. Lighting power for the endcap lighting measured 96 W; the savings calculation accounted for this power draw. These cases are served by four Copeland low temperature refrigeration compressors, which serve additional low temperature loads as well.

The test area base-case lighting is provided by F58T8 5-foot fluorescent lamps powered by solid-state ballasts. Lamps typically are situated vertically along the interior of each door frame. Where cases are adjacent to one another, two T8 lamps are on the same door beam. Ballasts are remote from the case in an insulated housing to prevent unnecessary heat gain to the refrigerated compartment. A total of 36 fluorescent lamps and associated ballasts provide illumination and power for the base-case lighting in the test area, excluding the endcaps. Figure 4.1 shows the refrigerator case with the fluorescent lighting.

The test-case lighting is provided by LED sources that consist of sixty 48-inch LED bars, LED Power model LB36X-WARP-100 as identified by CLTC, which is equivalent to two units per door. Each 48-inch length bar holds 144 LEDs, which are powered by LED driver units. The drivers observed during inspection were 80 W Advance model XITANIUM LEDA0024V33F0W, each powering three LED bars. As with the fluorescent system ballasts, the LED driver units were installed remote from the case so as to minimize unnecessary heat gain to the conditioned area. Figure 4.2 shows the refrigerator case with the LED lighting.

Baseline and test-case system datasheets are included in Appendix A, "Product Data Sheets".

Figure 4.1: Baseline Fluorescent Lighting System

Figure 4.2: Test-case LED Lighting System

4.3 Photometric Testing

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

- Measurement of vertical luminance on product shelf and luminance values of the entire case,
- Determination of light uniformity,
- Determination of correlated color temperature
- Determination of color rendering index
- Measurement of vertical illuminance on product shelf

In addition to establishing and refining a performance test protocol, CLTC's scope of work for this study was to perform measurements to characterize the baseline (fluorescent source) and test-case (LED source) conditions. CLTC further conducted analysis and interpretation of the data and prepared a photometric report. 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 10-minute intervals. This was the shortest interval at which the data logger could log one month's worth of data.

EES employed a Dent Elite-Pro data logger electric demand (kW) meter, which was installed and removed per the project schedule noted above. EES worked with the host customer's contract electrician onsite to identify the circuits powering the test area. The electrician accessed and operated the power panel while EES visually verified the loads to determine the correct circuits for monitoring. The project affects two circuits; these two circuits were monitored. EES worked with the electrician to install two current transducers (one per circuit), the data logger, and an external power source for the data logger. The data logger recorded volts, amps, power factor, kW, kVa, and kVar at 10 minute intervals for both circuits, one per channel.

EES additionally recorded spot field measurements at the circuit as well as at sample ballasts and LED drivers with a hand-held Fluke clamp-on multimeter. These measurements were used to corroborate the data logger results. The endcap lighting power draw of 96 W was determined in this manner.

Summary power data measurements are provided in Appendix C-1.

5. FACILITY INFORMATION

The host facility is a typical supermarket facility located in northern California. The facility is in the 40,000 square feet range. PG&E provides electrical service. Grocery stores of this type in PG&E's service territory normally qualify for an A-10 time-of-use electricity rate because they have a power demand between 200 and 500 kW. Information provided by PG&E account services indicates that most grocery store customers voluntarily elect to receive electricity service under the E19 rate schedule, for customers with a power demand greater than 500 kW. The actual utility information for this site is held confidentially by the owner and was not used in the development of this report.

Based on E-19 rate schedule information provided on PG&E's website, the average electricity cost was calculated to be $0.13196/kWh, including demand charges. Please refer to Appendix C-2 for rate information.

6. PROJECT RESULTS

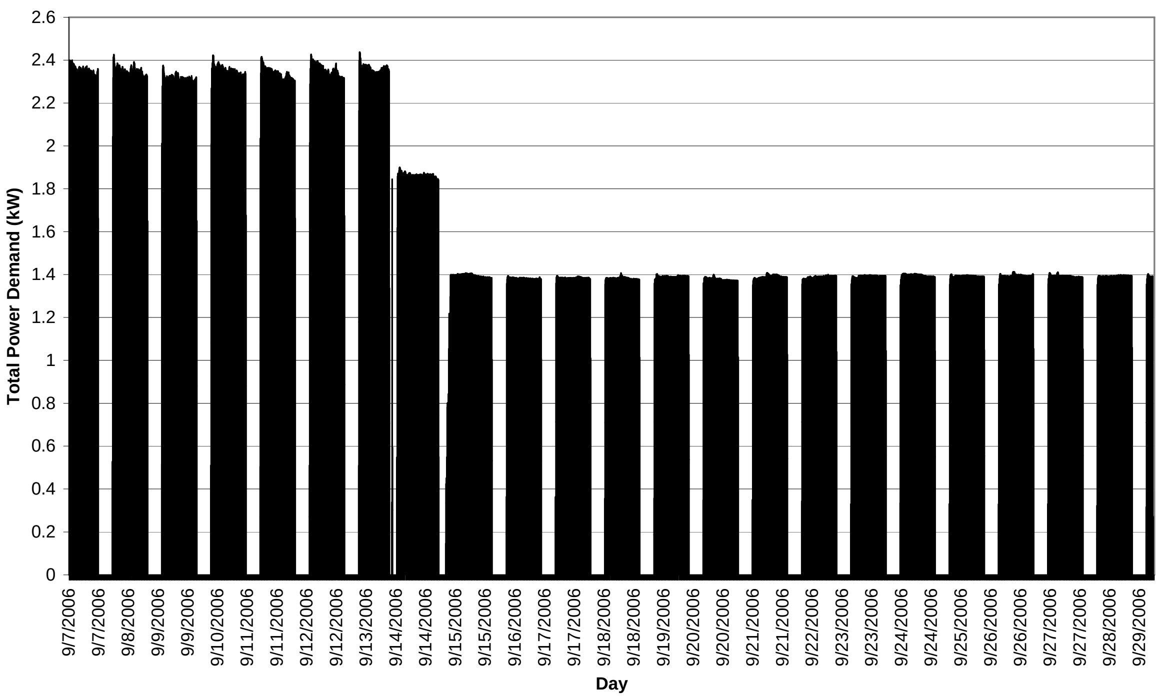
6.1 Electrical Energy and Demand Savings

The calculated savings are based on replacing 36 fluorescent lamps and associated ballasts with 60 LED bars in 6 freezer cases (i.e., 1 aisle, 30 doors). The average power data used in the calculations represent an entire metered circuit consisting of the lighting sources that serve these cases, including three T8 lamps located in endcap cases that were not replaced as a part of this project. The calculations for both the lighting retrofit and the impact of heat on the refrigeration system exclude the effect of the endcap lighting because it remains a constant lighting load of 96 W. Greater savings could be anticipated if the endcap lighting had likewise been changed.

Calculation of energy savings on a per-unit basis is not viable because the baseline and replacement quantities differ. For this report, a unit is considered a refrigeration aisle, which in this case consists of 30 doors and 6 Hussman cases.

Figure 6.1 illustrates the lighting load reduction associated with the project. September 14, 2006 was a transition day during which a portion of the lighting retrofit had been completed.

Figure 6.1: Measured Power, Fluorescent vs. LED



Energy Savings

Replacement of the base-case lighting system with test-case lighting resulted in a savings of 5,957 kWh per year in lighting savings, plus an estimated 2,854 kWh per year in refrigeration savings. The total project savings is calculated to be 8,811 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 17 hours per day. The recorded data support that the lighting operates continuously at regularly scheduled intervals, for approximately 17 hours per day. This is concluded because the data logger consistently registered no load for both of its channels during off periods. The data for the periods when the lighting was on prior to and through 9/13/06 (base case) was averaged for each channel and added to arrive at the base load of 2.29 kW. Similarly, the data for the periods when the lighting was on from 9/16/06 onwards (test case) was averaged for each channel and added to arrive at the test case load of 1.29 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. Refrigeration system savings were calculated based on the difference between the heat load generated within the conditioned area by the two light sources. This calculation used an assumed coefficient of performance (COP) of 2.0 for the refrigeration compressors. This is a conservative assumption of compressor efficiency taken from product literature provided by the manufacturer of low temperature refrigeration compressors.

Demand Savings

The calculated demand reduction for the lighting system replacement was 0.96 kW, based on the average connected loads derived from measured data. The load reduction on the refrigeration system was calculated to be 0.46 kW, on average. The calculated ratio of refrigeration system load reduction to lighting load reduction, about 50%, is corroborated by GE GELcore's reported results.[3]

The lighting systems operate continuously during the scheduled-on period for approximately 17 hours per day, 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, having been installed within the last 5 years. 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 test-case meets the user's requirements.

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

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 because the project replaces used capital equipment. Based on average life characteristics of the current and proposed equipment, more than three 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 for this case study to average approximately $375 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[4] 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 lighting 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^{o}): The absolute temperature of a blackbody radiator having a chromaticity equal to that of the light source.

Detailed information is provided in Appendix B, including CLTC measurements, luminance maps, graphs, photos and summary of key points.

[4] http://lightingdesignlab.com/library/glossary.htm; permission for reproduction of glossary granted by Diana Grant, Lighting Design Lab Project Manager, 10/25/06

Luminance

Luminance is commonly measured in candela per square meter, cd/m^2. Figure 6.2 compares the luminous intensity of the two sources, based on composite measurements performed in the vicinity of 11 doors at different locations as noted. The fluorescent sources consistently result in more luminance than do the LED, as shown. The fluorescent sources also provide slightly less variance in luminance between the left, right, and center of the cases.

Figure 6.3 compares the maximum and minimum luminance readings measured at the same doors as measured for Figure 6.2. LED provides more consistency in luminance values from door to door. The max.-min. ratio for LED at the center is 1.7 to 1 (1.7:1), compared with a max.-min. ratio of 3.3 to 1 (3.3:1) for the fluorescent sources.

Some fluorescent doors appear very dim, while other fluorescent doors are quite bright. This is supported by the max.-min. ratios calculated from the measured data. High luminance values are coincident with the impression of glare, which CLTC concludes is likely caused chiefly by overdriven fluorescent lamps, less so by product characteristics and placement. Minimum values suggest under-driven or failing fluorescent lamps.

Figure 6.2: Luminance Results

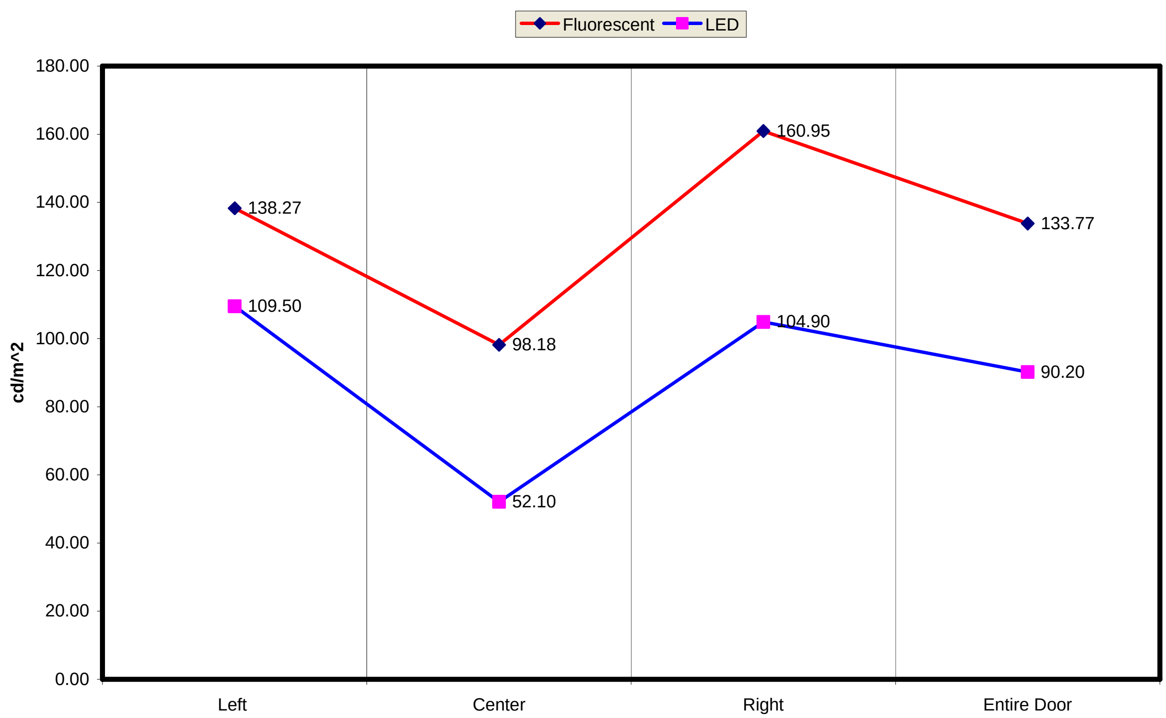
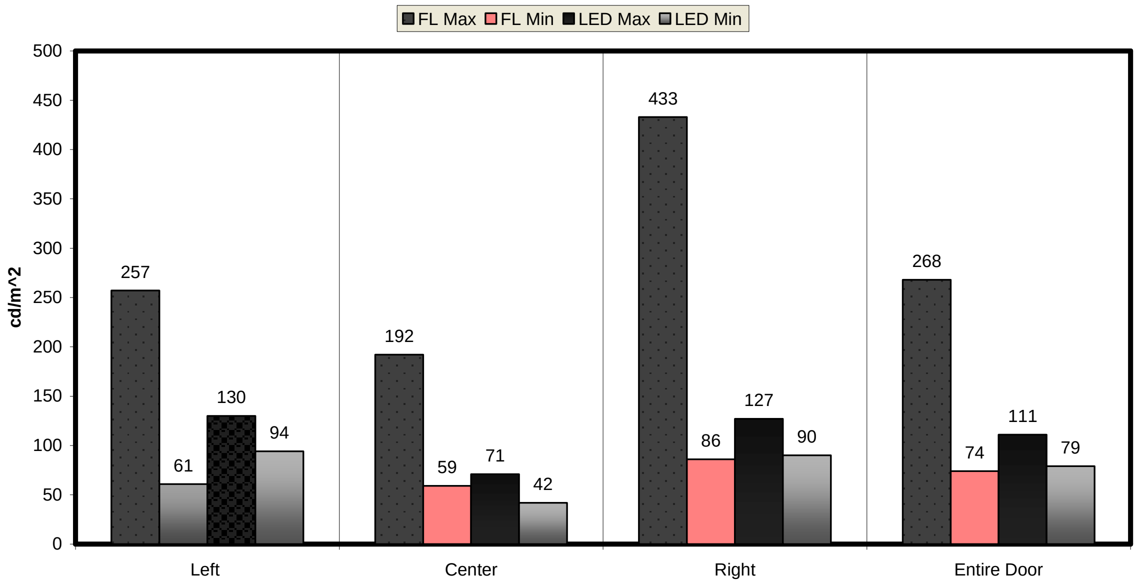


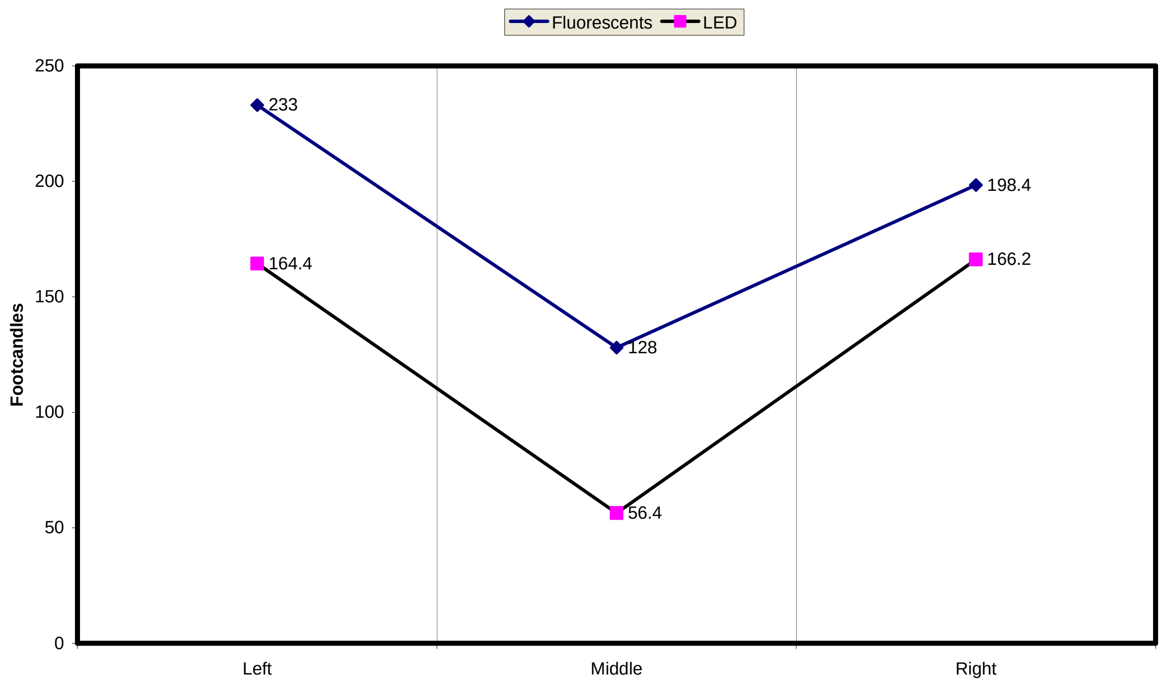
Figure 6.3: Max to Min Luminances - Composite



Illuminance

CLTC recorded illuminance values (light levels) for this project at the 14th door, and they are reported in footcandles. The results are shown in Figure 6.4. This chart shows a similar pattern in terms of distribution as are indicated by the composite luminance values shown in Figure 6.3.

Figure 6.4: Illuminance Results



Color Rendering Index (CRI)

The CRI for the LED source measured 77.5 in the CLTC lab. No CRI measurements for the fluorescent source are available for this study; however, the manufacturer rates the light source used in this study to have a CRI of 85. Higher CRI generally corresponds to a better quality of light. The CRI of the LED source exceeds the CRI of many of the fluorescent lamp types currently used in commercial refrigeration case lighting, such as cool white, high-output T12 lamps with a CRI of 62.

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 twice in the CLTC lab, with the results of 3431K and 3435K accordingly. In the field test-case, the LED source was measured at Door 14 to have a CCT of 3543K.

The fluorescent source, SLI F58T8/835, has a rated color temperature of 3500K. The color temperature of the fluorescent source was measured in the field at Door 14 to be 3208K, slightly warmer than expected.

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.

It should be noted that prior to the case lighting being re-lamped for the 100-hour lamp burn-in period required for this study, the case lighting was provided by fluorescent lamps with a rated CCT of 4100K. Both fluorescent and LED sources are available in a range of color temperatures.

6.4 Incremental Cost for Materials and Installation

The incremental cost for this measure as a retrofit is the actual installed cost. In the future if refrigeration cases are sold with an LED option, then the incremental cost of this measure will be the additional material cost only.

PG&E’s discussions with LED Power indicate that the current equipment cost for the light bars is about $200/door for a typical installation, including the driver component. LED Power expects the prices to drop to approximately $166.75 per door as the market matures.

As an estimate of labor costs, the installation of the light bars was completed by one electrician in about 20 hours. Labor cost was computed using the MEANS Electrical Cost Data Manual for 2006 with the appropriate northern California modifier, including overhead and profit.

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 several energy saving technologies. DEER does not provide a useful life value for LED 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[5], therefore the expected useful life of 50,000 hours assumed for this application is probably conservative.

[5] "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.

Also, as shown in Figure 6.3, 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 5.0 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"[6]. This demonstration project achieves a 43% reduction in lighting energy usage, plus additional refrigeration savings. It should be noted, however, that this 43% reduction in lighting energy use corresponds to a 33% reduction in luminance values. The reduction in total luminance may be mitigated based on system performance issues as discussed above.

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 higher energy savings. For example, since completion of the monitoring for this study, a more efficient power supply has been identified for use with refrigerated case LED lighting systems than that evaluated in this study. These forces combined are expected to result in continued improvement in the economics of LED technologies.

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

8. CONCLUSIONS

An active grocery 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 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 barrier to implementation traditionally is cost effectiveness. The data support a significant savings opportunity for the project in comparison with the cost of implementation. The cost effectiveness barrier can be overcome with maturing market conditions, vendor outreach, and utility incentive programs.

9. RECOMMENDATIONS FOR FUTURE WORK

This particular demonstration resulted in a reduction in measured illuminance. It is recommended that a follow-on study be conducted to measure customer satisfaction with the LED lighting systems, as well as the impact on sales, if any.

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 investor-owned 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.

EMCOR Energy Services

APPENDICES

EMCOR Energy Services

Appendix A
Product Data Sheets

Appendix A-1
Base Case System

T8 Med Bi Pin

Watts	Bulb	Base	Order Code SLi	Order Code Generic	Description		Pkg. Qty.	Nominal Lth.(in.)	Apprx. Hours	Initial Lumen	Design Lumen	CRI	Kelvin Temp
LuxLine T8 Terra-Lux													
17	T8	Med Bi Pin	01718		F17T8/730	Terra-Lux 700 Series	25	24	20000	1325	1200	75	3000
			01717		F17T8/735	Terra-Lux 700 Series	25	24	20000	1325	1200	75	3500
			01728		F17T8/741	Terra-Lux 700 Series	25	24	20000	1325	1200	75	4100
			01721		F17T8/830	Terra-Lux 800 Series	25	24	20000	1400	1315	85	3000
			01720		F17T8/835	Terra-Lux 800 Series	25	24	20000	1400	1315	85	3500
			01719		F17T8/841	Terra-Lux 800 Series	25	24	20000	1400	1315	85	4100
25	T8	Med Bi Pin	01724		F25T8/730	Terra-Lux 700 Series	25	36	20000	2125	1925	75	3000
			01723		F25T8/735	Terra-Lux 700 Series	25	36	20000	2125	1925	75	3500
			01722		F25T8/741	Terra-Lux 700 Series	25	36	20000	2125	1925	75	4100
			01727		F25T8/830	Terra-Lux 800 Series	25	36	20000	2250	2115	85	3000
			01726		F25T8/835	Terra-Lux 800 Series	25	36	20000	2250	2115	85	3500
			01725		F25T8/841	Terra-Lux 800 Series	25	36	20000	2250	2115	85	4100
32	T8	Med Bi Pin	01711	00630	F32T8/730	Terra-Lux 700 Series	25	48	20000	2850	2710	75	3000
			01712	00631	F32T8/735	Terra-Lux 700 Series	25	48	20000	2850	2710	75	3500
			01713	00632	F32T8/741	Terra-Lux 700 Series	25	48	20000	2850	2710	75	4100
			01705	00633	F32T8/750	Terra-Lux 700 Series	25	48	20000	2850	2710	75	5000
			01708	00634^	F32T8/830	Terra-Lux 800 Series	25	48	24000	3050	2895	85	3000
			01709	00635^	F32T8/835	Terra-Lux 800 Series	25	48	24000	3050	2895	85	3500
			01707		F32T8/841	Terra-Lux 800 Series	25	48	24000	3050	2895	85	4100
			01704		F32T8/850	Terra-Lux 800 Series	25	48	24000	3050	2895	85	5000
				17944	F32T8/EXCELLA		30	48	20000	2650	2895	91	5765
58	T8	Med Bi Pin	01741		F58T8/841		25	60	15000	5200	4840	85	4100
70	T8	Med Bi Pin	01751		F70T8/841		25	72	15000	6000	5580	85	4100
Pre-Heat													
15	T8	Med Bi Pin	01714		F15T8/CW		25	18	10000	870	765	62	4100
			01715		F15T8/D		25	18	10000	870	765	76	6500
				17920	F15T8/EXCELLA		24	18	7500	870	765	91	5765
30	T8	Med Bi Pin		60412	F30T8/CW		30	36	7500	2200	2000	62	4100
Instant Start T8													
59	T8	Single Pin	60453		F96T8/730		24	96	15000	5700	5190	75	3000
			60439		F96T8/735		24	96	15000	5700	5190	75	3500
			60438		F96T8/741		24	96	15000	5700	5190	75	4100

^ Available Until Inventory Depleted

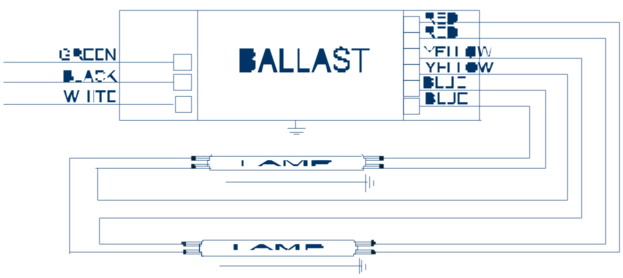
ADVANCE

Electrical Specifications

ICN-2S54@120V	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Lamp Type	Num. of Lamps	Rated Lamp Watts	Min. Start Temp (°F/C)	Input Current (Amps)	Input Power (ANSI Watts)	Ballast Factor	MAX THD %	Power Factor	MAX Lamp Current Crest Factor	B.E.F.
F58T8	1	58	-20/-29	0.49	58	1.00	10	0.99	1.7	1.72
* F58T8	2	58	-20/-29	0.97	116	1.00	10	0.99	1.7	0.86

Wiring Diagram



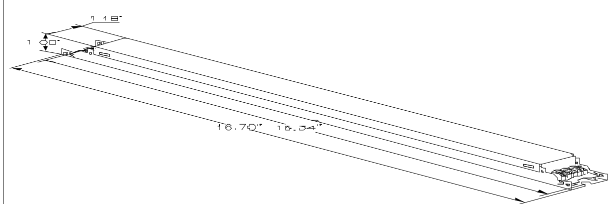
The wiring diagram that appears above is for the lamp type denoted by the asterisk (*)

Standard Lead Length (inches)

	in.	cm.
Black	0.0	0
White	0.0	0
Blue	0.0	0
Red	0.0	0
Yellow	0.0	0
Gray		0
Violet		0

	in.	cm.
Yellow/Blue		0
Blue/White		0
Brown		0
Orange		0
Orange/Black		0
Black/White		0
Red/White		0

Enclosure



Enclosure Dimensions

OverAll (L)	Width (W)	Height (H)	Mounting (M)
16.70 "	1.18 "	1.00 "	16.34 "
16 7/10	1 9/50	1	16 17/50
42.4 cm	3 cm	2.5 cm	41.5 cm

Revised 10/13/2006

ADVANCE
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Corporate Offices: Phone: 800-322-2086

Electrical Specifications

ICN-2S54@120V	
Brand Name	CENTIUM T5
Ballast Type	Electronic
Starting Method	Programmed Start
Lamp Connection	Series
Input Voltage	120-277
Input Frequency	50/60 HZ
Status	Active

Notes:

Section I - Physical Characteristics

1.1 Ballast shall be physically interchangeable with standard electromagnetic or standard electronic ballasts, where applicable.

1.2 Ballast shall be provided with integral leads or poke-in wire trap connectors color-coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Ballast shall be Programmed Start.

2.2 Ballast shall contain auto restart circuitry in order to restart lamps without resetting power.

2.3 Ballast shall operate from 50/60 Hz input source of ___________________ (120V through 277V or 347V through 480V) with sustained variations of +/- 10% (voltage and frequency) with no damage to the ballast.

2.4 Ballast shall be high frequency electronic type and operate lamps at a frequency above 42 kHz to avoid interference with infrared devices and eliminate visible flicker.

2.5 Ballast shall have a Power Factor greater than 0.98 for primary lamp.

2.6 Ballast shall have a minimum ballast factor of 1.00 for primary lamp application.

2.7 Ballast shall provide for a Lamp Current Crest Factor of 1.7 or less in accordance with lamp manufacturer recommendations.

2.8 Ballast input current shall have Total Harmonic Distortion (THD) of less than 20% for Standard models and THD of less than 10% for Centium models when operated at nominal line voltage with primary lamp.

2.9 Ballast shall have a Class A sound rating.

2.10 Ballast shall have a minimum starting temperature of _______ {-18C (0F) or -28C (-20F)} for primary lamp. Consult lamp manufacturer for temperature versus light output characteristics.

2.11 Ballast shall provide Lamp EOL Protection Circuit.

2.12 Ballast shall tolerate sustained open circuit and short circuit output conditions without damage.

2.13 Ballast shall have a hi-low switching option when operating (4) F54T5/HO lamps to allow switching from 4-2 lamps, 3-2 lamps or 3-1 lamp.

2.14 Four-lamp ballast shall have semi-independent lamp operation.

Section III - Regulatory Requirements

3.1 Ballast shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Ballast shall be Underwriters Laboratories (UL) listed, Class P and Type 1 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Ballast shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Ballast shall comply with ANSI C82.11 where applicable.

3.5 Ballast shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 18, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

3.6 Ballast shall comply with UL Type CC rating.

Section IV - Other

4.1 Ballast shall be manufactured in a factory certified to ISO 9002 Quality System Standards.

4.2 Ballast shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 70C. Ballasts with a "90C" designation in their catalog number shall also carry a three-year warranty at a maximum case temperature of 90C.

4.3 Manufacturer shall have a fifteen-year history of producing electronic ballasts for the North American market.

4.4 Ballast shall be Advance part # _____________ or approved equal.

Revised 10/13/2006

ADVANCE TRANSFORMER CO.
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ROSEMONT, ILLINOIS 60018
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Appendix A-2
Test Case System

PIRANHA 36 LED LIGHT BAR WHITE

HOW TO READ AN LED POWER PART NUMBER:

LB 36 1 - XXX P - 100

LB IS SIMPLY TO IDENTIFY THE PART NUMBER INTO THE LIGHT BAR CATEGORY.

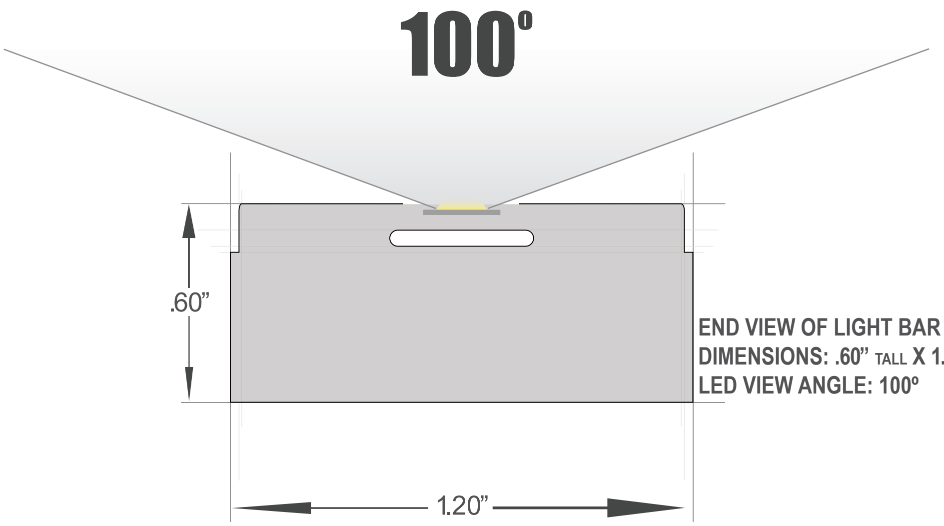
THESE TWO NUMBERS ARE HOW MANY LED LIGHTS PER FOOT ARE IN THE LIGHT BAR.

THIS NUMBER INDICATES THE LENGTH OF THE LIGHT BAR IN FEET.
IT WILL EITHER BE 6",1, 2, 3, OR 4.

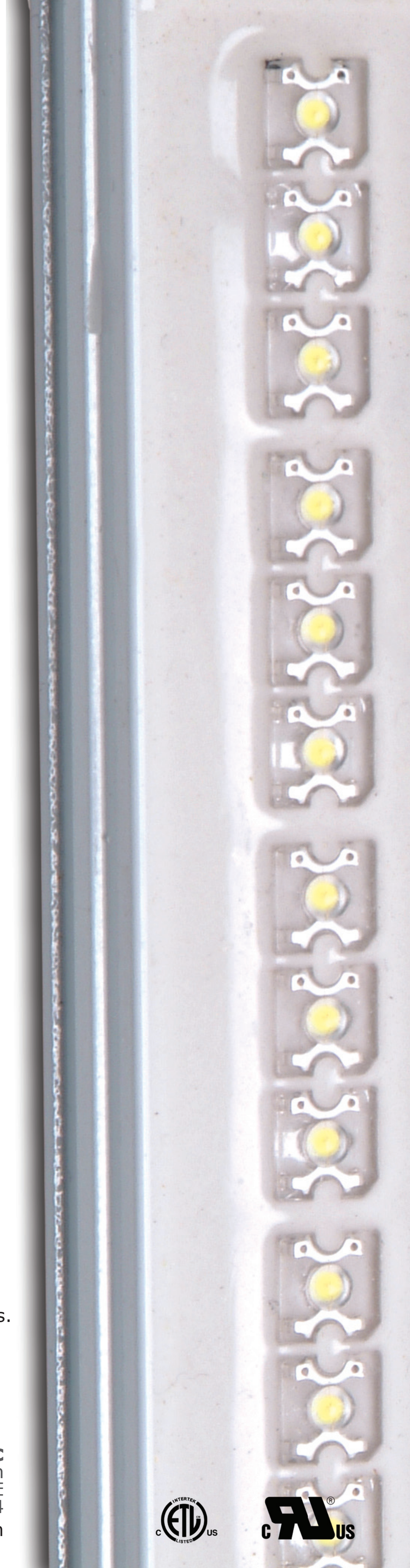
THESE THREE LETTERS REPRESENT THE COLOR OF THE LED LIGHTS IN THE LIGHT BAR.

THIS LETTER STANDS FOR THE TYPE OF LED USED. P = PIRANHA STYLE SUPER FLUX LED.
5 = 5MM LED. O = OVAL 100º/40º LED.

THIS NUMBER REPRESENTS THE VIEW ANGLE OF LIGHT EMITTED FROM THE LED.



END VIEW OF LIGHT BAR
DIMENSIONS: .60" TALL X 1.20" WIDE
LED VIEW ANGLE: 100º



- This product is ETL Listed and confirms to UL Standard 1598.
- Certified to CAN/CSA Standard 22.2 No. 250.0-04.
- High-Quality LED based Light Bars are available in an array of colors and lengths.
- Choose from 6 inch to 4 foot long lengths with your choice of LED.
- Low-Wattage, Low-Voltage and very Low-Heat with 12VDC Operation.
- White Color Kelvin Temperatures from 2800°K, 3500°K, 5000°K & 8000°K.
- Mono Colors available in Red, Amber, Blue & Green.
- RGB with DMX compatible controllers also available for your color changing projects.
- Light Bars have LED view angles that are customizable from 20° to 120°.
- Ridged Aluminum Light Bars come fully silicone potted for added durability.
- User friendly, easy installation with quality end-to-end connections and brackets.
- Suitable for damp locations.

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

LIGHT BAR ELECTRICAL SPECIFICATIONS

PART NUMBER	DESIGN VOLTAGE	TYPICAL CURRENT	TYPICAL WATTS	MAX (LOAD) AMPS PER RUN	MAX (LOAD) WATTS PER RUN
LB361-XXXP-100	12 VDC	0.33A	4W	5 Amps	60W
LB362-XXXP-100		0.66A	8W		
LB363-XXXP-100		0.99A	12W		
LB364-XXXP-100		1.33A	16W		

LIGHT BAR DIMENSIONS

PART NUMBER	LEDS PER FOOT	LEDs	LIGHT BAR LENGTH	ALUMINUM EXTRUSION
LB361-XXXP-100	36	36	L = 317.50mm (12.5”)	30mm Wide 15mm High
LB362-XXXP-100		72	L = 622.30mm (24.5”)	
LB363-XXXP-100		108	L = 927.10mm (36.5”)	
LB364-XXXP-100		144	L = 1231.9mm (48.5”)	

LED SPECIFICATIONS

PART NUMBER	LED COLOR	TYPICAL KELVIN	VIEW ANGLE	TYPICAL LUMENS PER FOOT
LB36X-WASP-100	Super Warm White	2800ºK	100º	130 lm
LB36X-WARP-100	Warm White	3500ºK	100º	144 lm
LB36X-WCOP-100	Cool White	5000ºK	100º	159 lm
LB36X-WBTP-100	Bright White	8000ºK	100º	172 lm

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ADVANCE

Xitanium™
LED Drivers

Drivers for 12vdc and 24vdc LED Systems

Applications

Orientation/step lighting
Architectural lighting
Cove lighting
Casino/entertainment lighting
Undercabinet lighting
Channel letters
Contour lighting
Edge lighting

LEDs have evolved into a practical, flexible light source for a wide variety of illumination applications. Common LED products available in the market today are configured in a series-parallel array—designed to be powered by a suitable 12vdc or 24vdc driver – which allows flexibility to connect variable load levels. These operating voltages have become the standard in the industry.

The Brain Behind the Bright Idea
Xitanium LED drivers from Advance Transformer Company are designed specifically for 12vdc and 24vdc LED systems and incorporate features that enable broad commercialization of end-use solid-state lighting products.

Features	Benefits
UL Class 2	Limited output voltage and current plus isolation for safe operation
Damp location rating available (UL 935 Outdoor Type II)	Fully potted for moisture resistance and thermal transfer benefits
Small, compact size	Facilitates new, low-profile fixture design
Inherent short circuit protection	Added safety...without any troublesome fuses
Extreme low temperature performance (-40°C)	Allows use in any outdoor application
Generous high temperature capability (+60°C ambient; 80°/90°C case rating)	Margin flexibility to facilitate fixture design
Tightly regulated output (1% line, 5% load)	Consistent light output across line and load levels
5 year warranty	Peace of mind for your new products and for end users...from the industry's most trusted component maker
Powered by Advance	Advance is preferred by end users – Enhance the value of your product

LED Driver Specifications

Description	Catalog Number	Input			Output			Max Allowable Case Temp (C)	Figure	Weight (lbs.)
		Volts (60 hz)	Power, Max (W)	Current, Max (A)	Power, Min (W)	Power, Max (W)	Current, Max (A)			
12VDC LED Systems										
12 Watt	LED-120A-0012V-10F	120 +/- 10%	15.0	0.14	2.0	12.0	1.0	85	C	0.14
25 Watt	LED-120A-0012V-21F	120 +/- 10%	21.5	0.20	2.3	25.5	2.1	85	B	0.32
60 Watt	LED-120A-0012V-50F	120 +/- 10%	75.0	0.70	10.0	60.0	5.0	90	D	1.50
240 Watt	LED-120A-0012V-50F4*	120 +/- 10%	275.0	2.55	10.0	60.0	5.0	80	E	6.00
24VDC LED Systems										
17 Watt	LED-120A-0024V-07F	120 +/- 10%	21.5	0.20	2.4	17.2	0.7	90	A	0.14
25 Watt	LED-120A-0024V-10F	120 +/- 10%	31.9	0.30	2.3	25.5	1.05	80	B	0.32
25 Watt Dimming	LED-120A-0024V-10D**	120 +/- 10%	31.9	0.30	15.0	25.5	1.05	80	B	0.32
40 Watt	LED-120A-0024V-18F	120 +/- 10%	51.0	0.47	3.5	40.8	1.75	85	B	0.32
80 Watt	LED-120A-0024V-33F	120 +/- 10%	100.0	0.90	15.0	80.0	3.3	90	D	1.50
240 Watt	LED-120A-0024V-25F4*	120 +/- 10%	275.0	2.55	10.0	60.0	2.5	80	E	6.00

*Driver has four independent output channels. Output data is "per channel", input data is total.

**For complete specifications of dimming driver, see Advance Form No. LE-6010 available at www.advancetransformer.com

Total Harmonic Distortion: 20% max
Power Factor: 90% minimum
Efficiency: 80% typical
Line Regulation: 1% output voltage variation across input voltage range
Load Regulation: 5% output voltage variation across load range
Current Crest Factor: 1.5 Maximum
UL and C-UL Recognized
UL File Number E220165; 12, 60, 80 and 240 watt damp location rated; 17, 25 and 40 watt dry location only
EMI: FCC Class A or B
Protection: Inherent short-circuit protection, self limited; overload protected; 3.2kv 60hz output insulation
Humidity: 80% RH

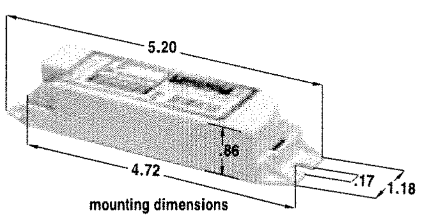

Figure A AC input: WAGO 2-pin wire trap, 28AWG solid or tinned stranded wire Line (black), Neutral (white)
DC output: Use Tyco-AMP connection cable 1365323-1 (not provided)

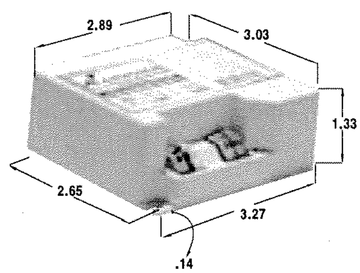

Figure B AC input: WAGO 2-pin wire trap, 18AWG solid or tinned stranded wire Line (black), Neutral (white) Ground (green)
DC output: WAGO 4-pin wire trap, 20AWG solid or tinne stranded wire Positive (red) Negative (blue), 0 – 10vdc dimming controls, if applicable (violet and grey)

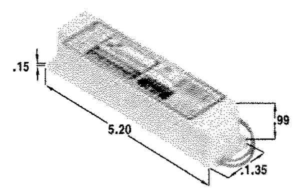

Figure C AC input: 6-inch 18AWG leads Line (black), Neutral (white)
DC output: 6-inch 18AWG leads Positive (red), Negative (blue)

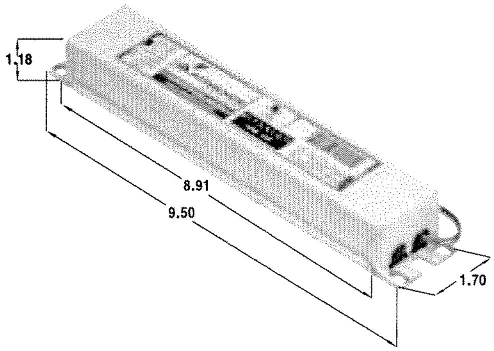

Figure D AC input: 9-inch 18AWG leads Line (black) Neutral (white)
DC input: 9-inch 18AWG leads Positive (red), Negative (blue)

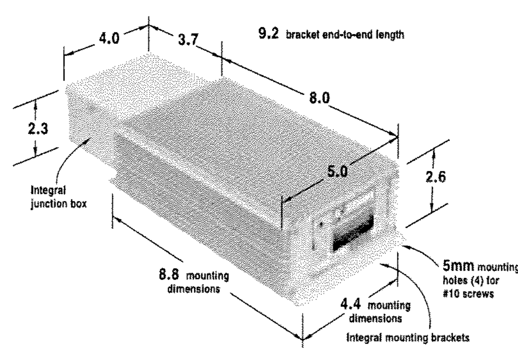

Figure E AC input: 6-inch 18AWG leads Line (black) Neutral (white), Ground (green)
DC output: 4 pairs of 6-inch 18AWG leads Positive (red), Negative (blue)

ADVANCE

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Customer Support/Technical Service: (800) 372-3331
www.advancetransformer.com
A DIVISION OF PHILIPS ELECTRONICS NORTH AMERICA CORPORATION

Form No. LE-6050-R01 8/03

SECTION V – Xitanium™ LED Drivers

Ballast Specification for Xitanium™ LED Drivers

Xitanium™

Section I - Physical Characteristics

1.1 Driver shall be available in a plastic/metal can or all metal can construction to meet all plenum requirements.

1.2 Driver shall be provided with poke-in wire trap connectors or integral leads color coded per ANSI C82.11.

Section II - Performance Requirements

2.1 Driver shall operate from 60 Hz input source of 120V with sustained variations of +/- 10% (voltage and frequency) with no damage to the Driver.

2.2 Driver output shall be regulated to +/- 5% across published load range.

2.3 Driver shall operate LEDs at a frequency of 60 Hz.

2.4 Driver shall have a Power Factor greater than 0.90 for primary application.

2.5 Driver input current shall have Total Harmonic Distortion (THD) of less than 20%.

2.6 Driver shall have a Class A sound rating.

2.7 Driver shall have a minimum operating temperature of -40C (-40F).

2.8 Driver shall tolerate sustained open circuit and short circuit output conditions without damage and without need for external fuses or trip devices.

Section III - Regulatory Requirements

3.1 Driver shall not contain any Polychlorinated Biphenyl (PCB).

3.2 Driver shall be Underwriters Laboratories (UL) listed, Class 2 Outdoor; and Canadian Standards Association (CSA) certified where applicable.

3.3 Driver shall comply with ANSI C62.41 Category A for Transient protection.

3.4 Driver shall comply with the requirements of the Federal Communications Commission (FCC) rules and regulations, Title 47 CFR part 15, Non-Consumer (Class A) for EMI/RFI (conducted and radiated).

Section IV - Other

4.1 Driver shall be manufactured in a factory certified to ISO 9002 Quality System Standards.

4.2 Driver shall carry a five-year warranty from date of manufacture against defects in material or workmanship, including replacement, for operation at a maximum case temperature of 90C.

4.3 Manufacturer shall have a fifteen year history of producing electronic ballasts for the North American market.

4.4 Dimmable drivers shall be controlled by a Class 2 low voltage 0-10VDC controller.

4.5 Driver shall be Advance Transformer part # ____________ or approved equal.

Appendix B

Photometric Test Protocol and Testing Results

Appendix B-1
CLTC Lighting Test Protocol

Draft Photometric Testing Protocol for Lighting System Evaluation in Reach-in Freezer Cases

Introduction

The purpose of this document is to define a repeatable photometric testing procedure to characterize the lighting system performance in reach-in freezer cases. All tests shall be conducted in the freezer case when at steady state at its normal operating temperature. Freezer case must be left closed during all measurements and all condensation must be absent from door.

Step 1 Measure vertical luminance on product shelf

1. Shelf setup variables:
   a. Shelf color
   b. Shelf distance apart
   c. Number of shelves
2. Measure luminance values of the entire case. The camera will be approximately 3 feet away from the glass doors in the center of the freezer case.
3. The average luminance from center, left, right and entire door will be included in each map.

Step 2 Determine light uniformity and source image

1. Based on luminance map standard deviation from Step the uniformity can be determined.

Step 3 Determine Correlated Color Temperature (CCT)

1. Use a chroma-meter or spectral-photometer located outside the freezer measure CCT.

Step 4 Determine Color Rendering Index (CRI)

1. Use a portable spectral-photometer located outside the freezer to determine CRI. If a portable spectral-photometer cannot isolate the light source then take a sample source to the lab for testing.

Step 5 Measure vertical illuminance on product shelf.

1. Use a Minolta meter to take 3 illuminance measurements on each shelf. Measurements should be taken about 5 inches toward the center of the shelf from the mullion on the left and right side and in the center of the shelf. Measurements should be taken in the front of the shelf, about 7 inches off the shelf surface.

Step 6 Determine power usage.

1 EMCOR will be handling all power measurements.

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Appendix B-2
CLTC Measurement and Illuminance Maps

Grocery Store Analysis

CLTC
Michael Gross, Dev. Engineer
Keith Graeber, Dev. Engineer

T8 Fluorescent vs. LED Power

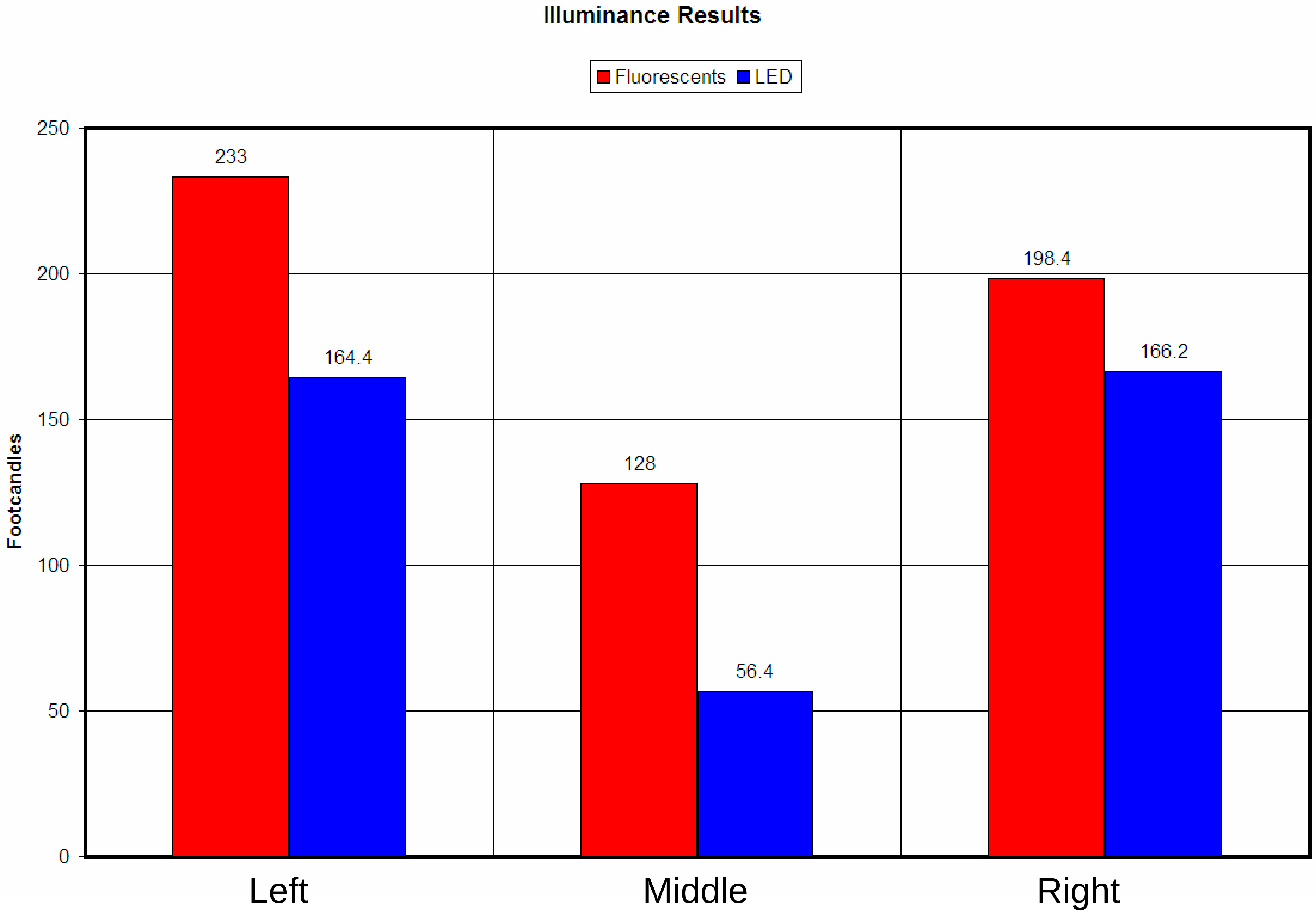
- T8 and LED lamps have approximately 150 hrs burn time.
- All pictures in this report are taken at same F-stop and exposure time for equal comparison.
- Measurements taken on 2 separate days:

  Fluorescents – 9/7/06

  LED’s – 9/29/06

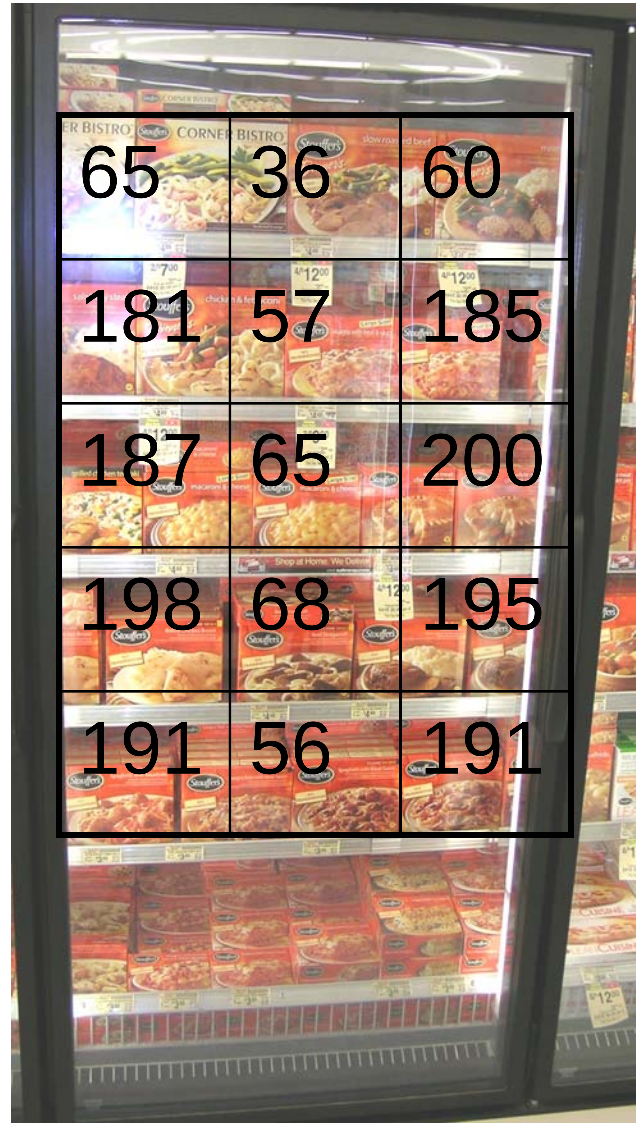
Illuminance Meter Setup

Average Illuminance Measurements



Illuminance Measurements

Fluorescent



LED

Illuminance Measurements

Measured on-site **Fluorescents**

9/7/2006

Illuminance measurements at 14th door under 'dinner' sign - left door under sign

	1	2	3		
	Left	Middle	Right		CCT = 3208
	150	88	115	68	
	247	122	182	58	
	252	130	200	48	Inches off ground to shelf
	260	150	228	38	
	256	150	267	28	
Average	**233**	**128**	**198.4**		**186** **Average**

measurements taken 7.5 Inches above shelf

Measured on-site **LED**

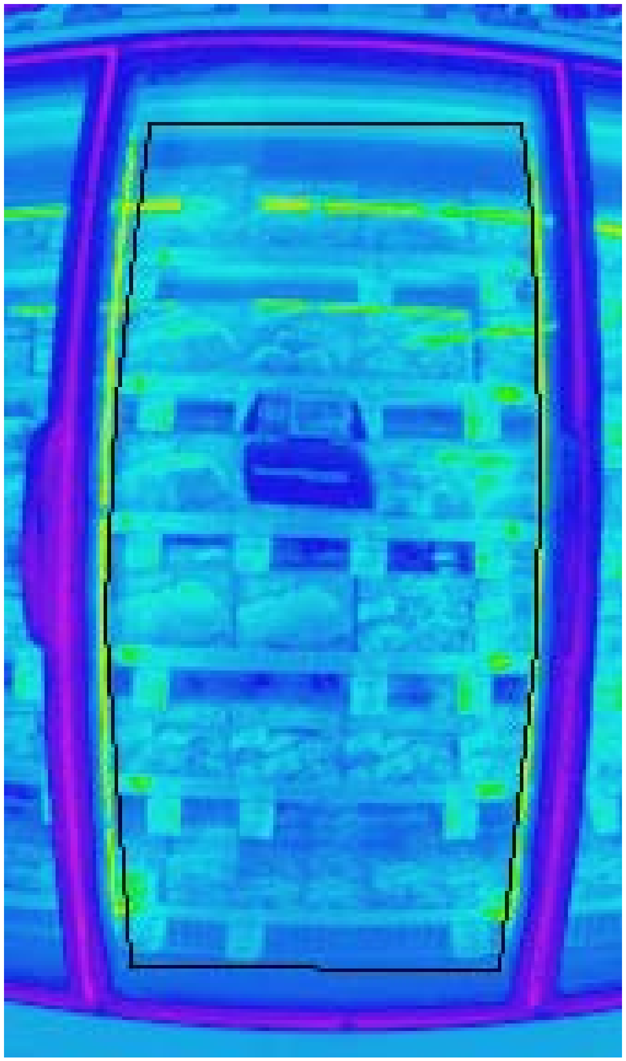
9/29/2006

Illuminance measurements at 14th door under 'dinner' sign - left door under sign

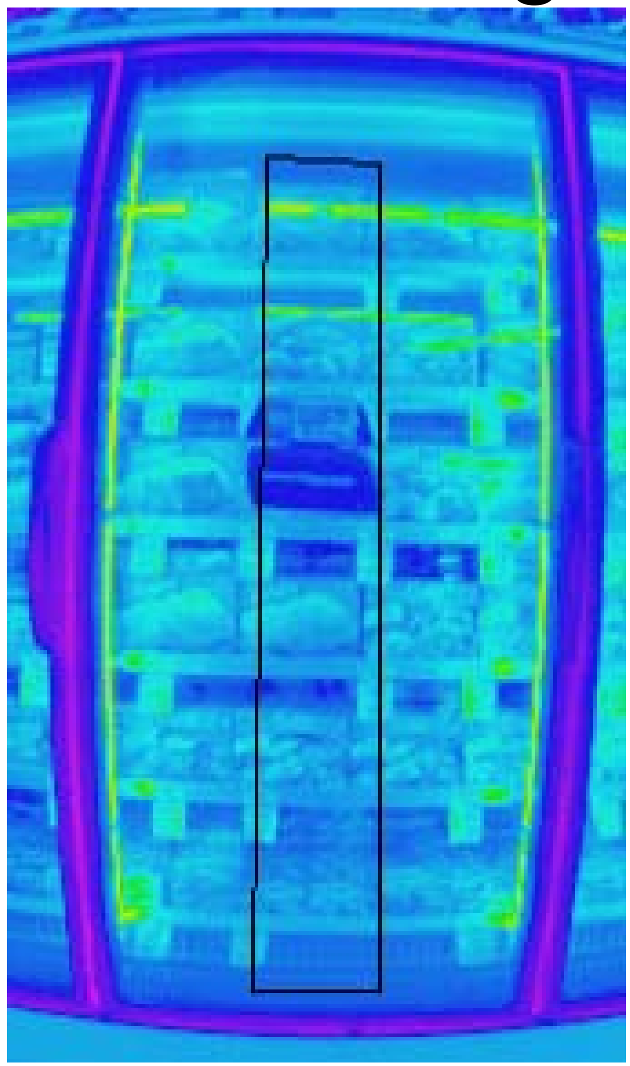
	1	2	3		
	Left	Middle	Right		CCT = 3543
	65	36	60	68	
	181	57	185	58	
	187	65	200	48	Inches off ground to shelf
	198	68	195	38	
	191	56	191	28	
Average	**164.4**	**56.4**	**166.2**		**129** **Average**

measurements taken 7.5 Inches above shelf

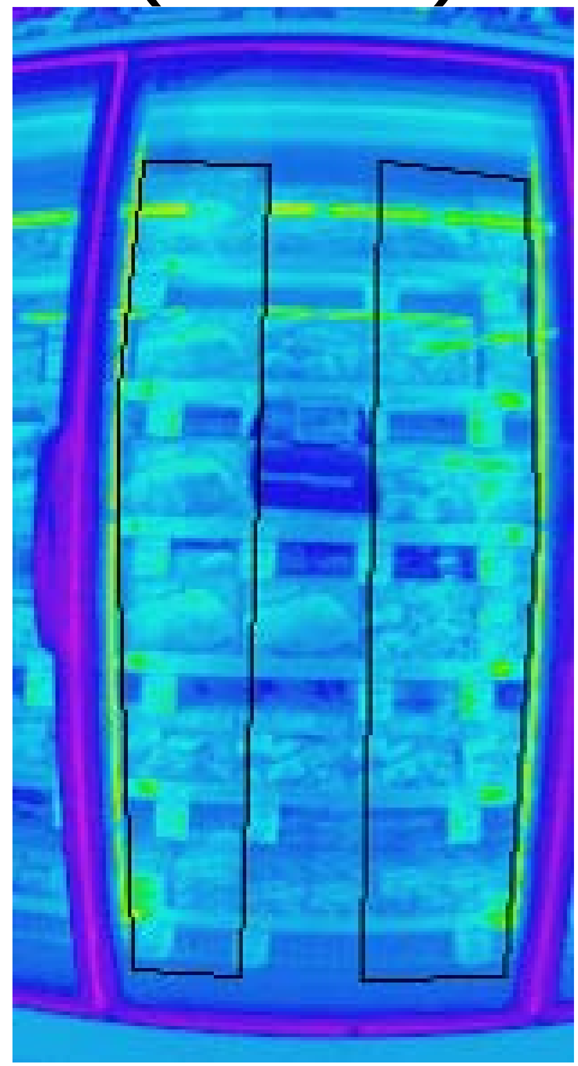
Avg. Luminance of Regions (cd/m^2)



Entire Door

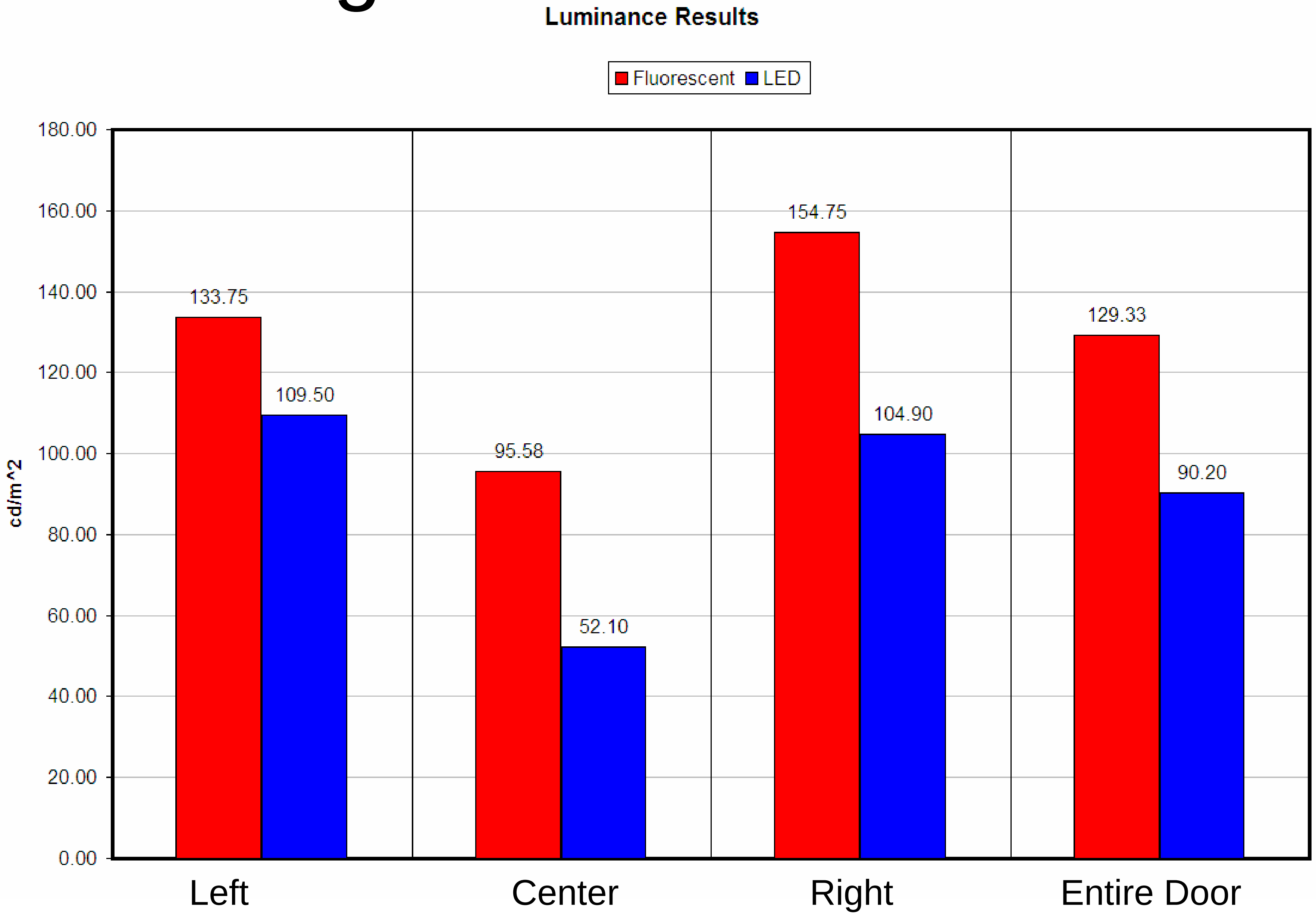


Center Door



Left and Right
Side Door

Average Luminance Results

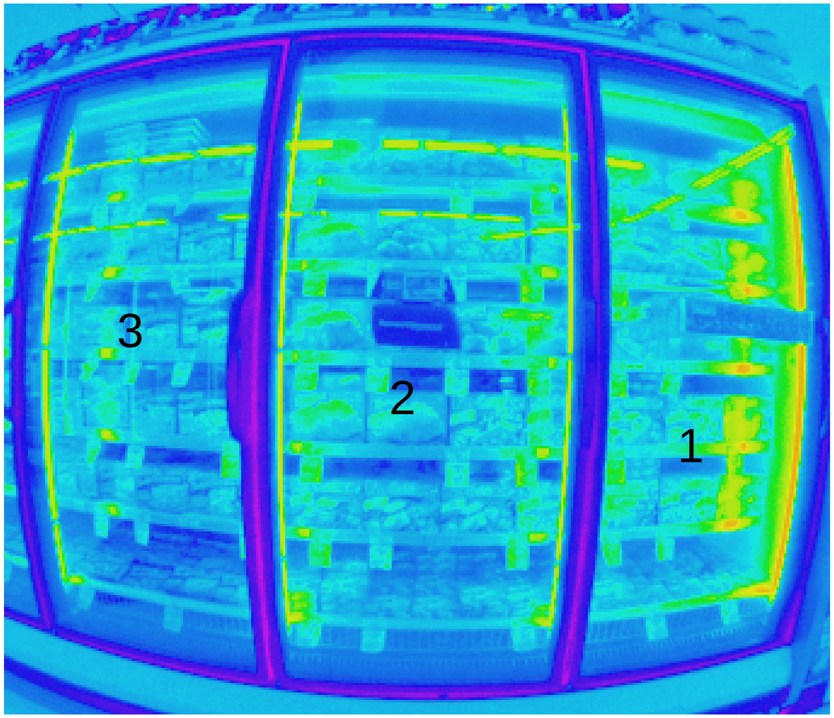


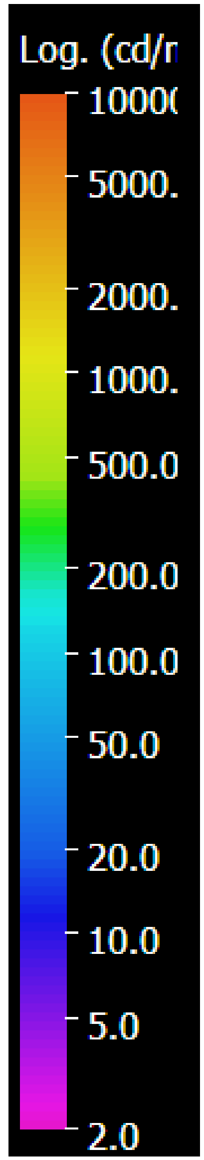
Summary of Luminance values cd/m^2

Luminance results								
	Fluorescent				**LED**			
	Left	Center	Right	Entire Door	Left	Center	Right	Entire Door
Door 2	127	80	126	112	105	54	98	88
Door 5	148	82	130	120	103	46	92	79
Door 8	142	98	127	123	106	49	106	89
Door 11	183	192	433	268	130	71	127	111
Door 14	87	65	87	78	104	42	90	81
Door 17	61	59	98	74	117	44	98	88
Door 20	257	119	155	183	102	52	120	94
Door 23	141	92	118	116	94	51	102	85
Door 26	161	113	249	180	107	54	99	86
Door 29	130	113	161	137	127	58	117	101
Door 32	85	74	87	85				
Repeat 32	83	60	86	76				
Max	257	192	433	268	130	71	127	111
Min	61	59	86	74	94	42	90	79
Average	**133.75**	**95.58**	**154.75**	**129.33**	**109.50**	**52.10**	**104.90**	**90.20**

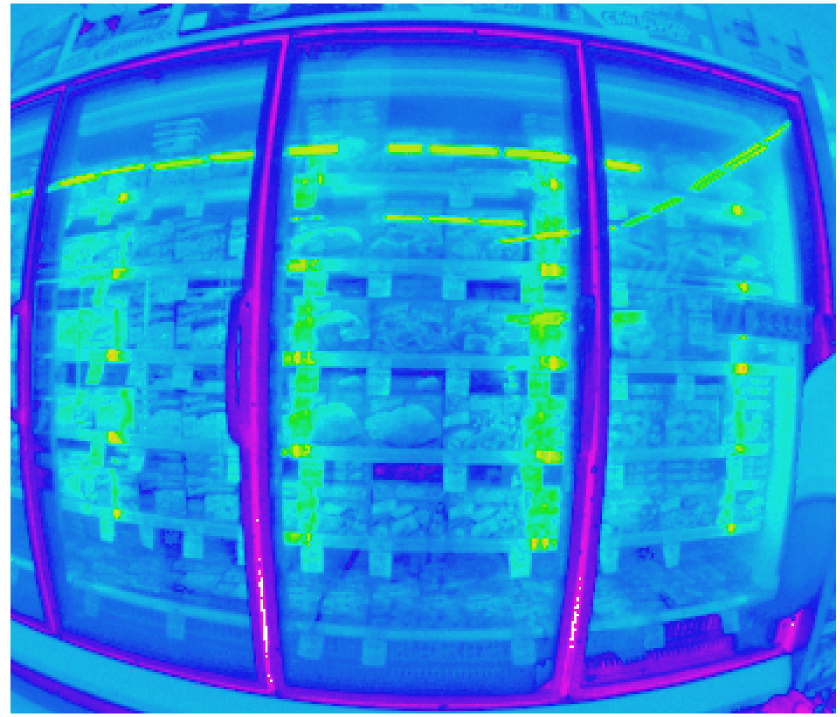
Door 2

Fluorescent





LED



Door Avg: 112

Center Avg: 80

Left Side Avg: 127

Right Side Avg: 126

Both Sides Avg: 126.5

Luminance Averages: cd/m^2

Door Avg: 88

Center Avg: 54

Left Side Avg: 105

Right Side Avg: 98

Both Sides Avg: 102

Door 2

Fluorescent

LED

GLARE

Door Avg: 112

Center Avg: 80

Left Side Avg: 127

Right Side Avg: 126

Both Sides Avg: 126.5

Door Avg: 88

Center Avg: 54

Left Side Avg: 105

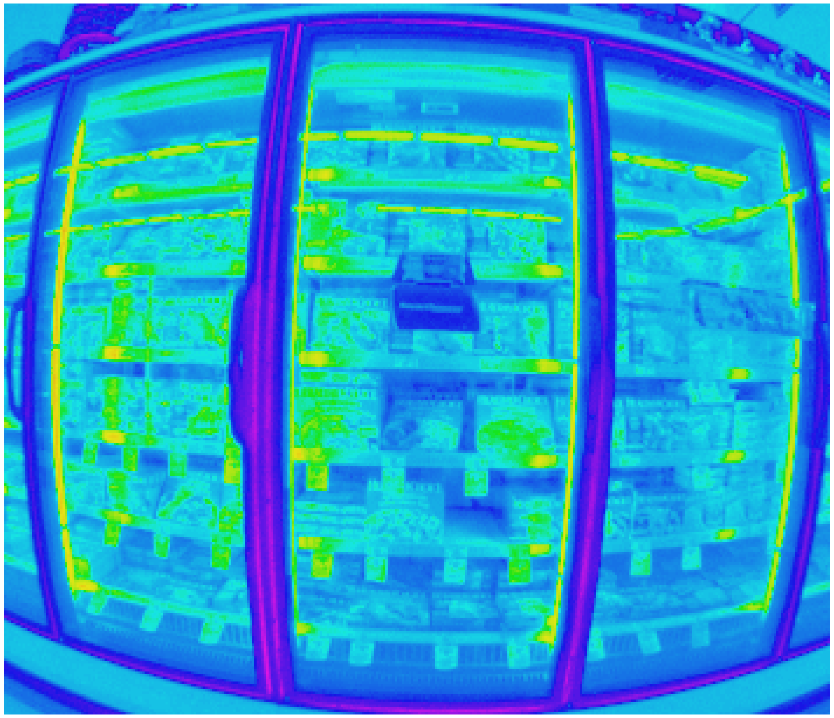
Right Side Avg:98

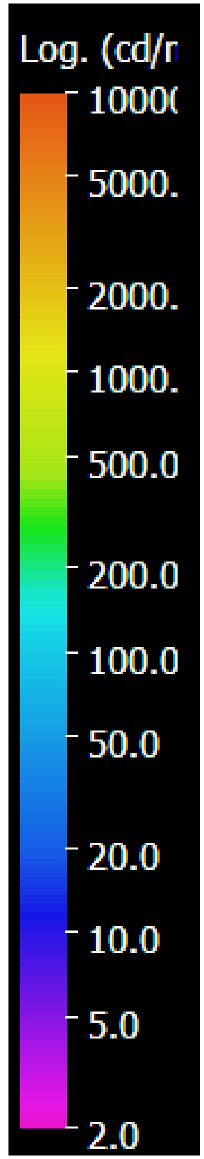
Both Sides Avg:102

Luminance Averages: cd/m^2

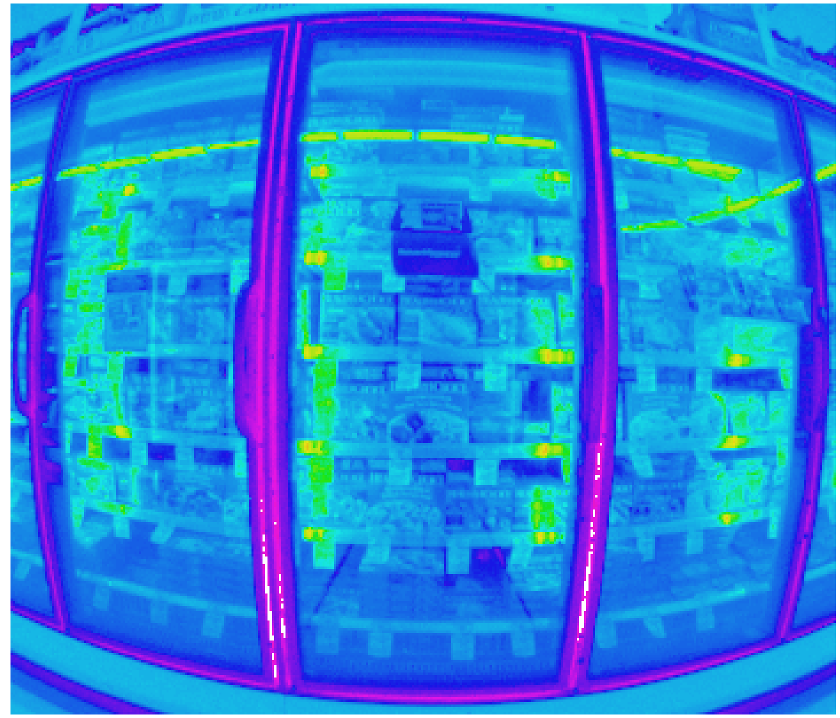
Door 5

Fluorescent





LED



Door Avg: 120

Center Avg: 82

Left Side Avg: 148

Right Side Avg: 130

Both Sides Avg: 139

Door Avg: 79

Center Avg: 46

Left Side Avg: 103

Right Side Avg:92

Both Sides Avg: 97.5

Luminance Averages: cd/m^2

Door 5

Fluorescent

Door Avg: 120

Center Avg: 82

Left Side Avg: 148

Right Side Avg: 130

Both Sides Avg: 139

LED

Door Avg: 79

Center Avg: 46

Left Side Avg: 103

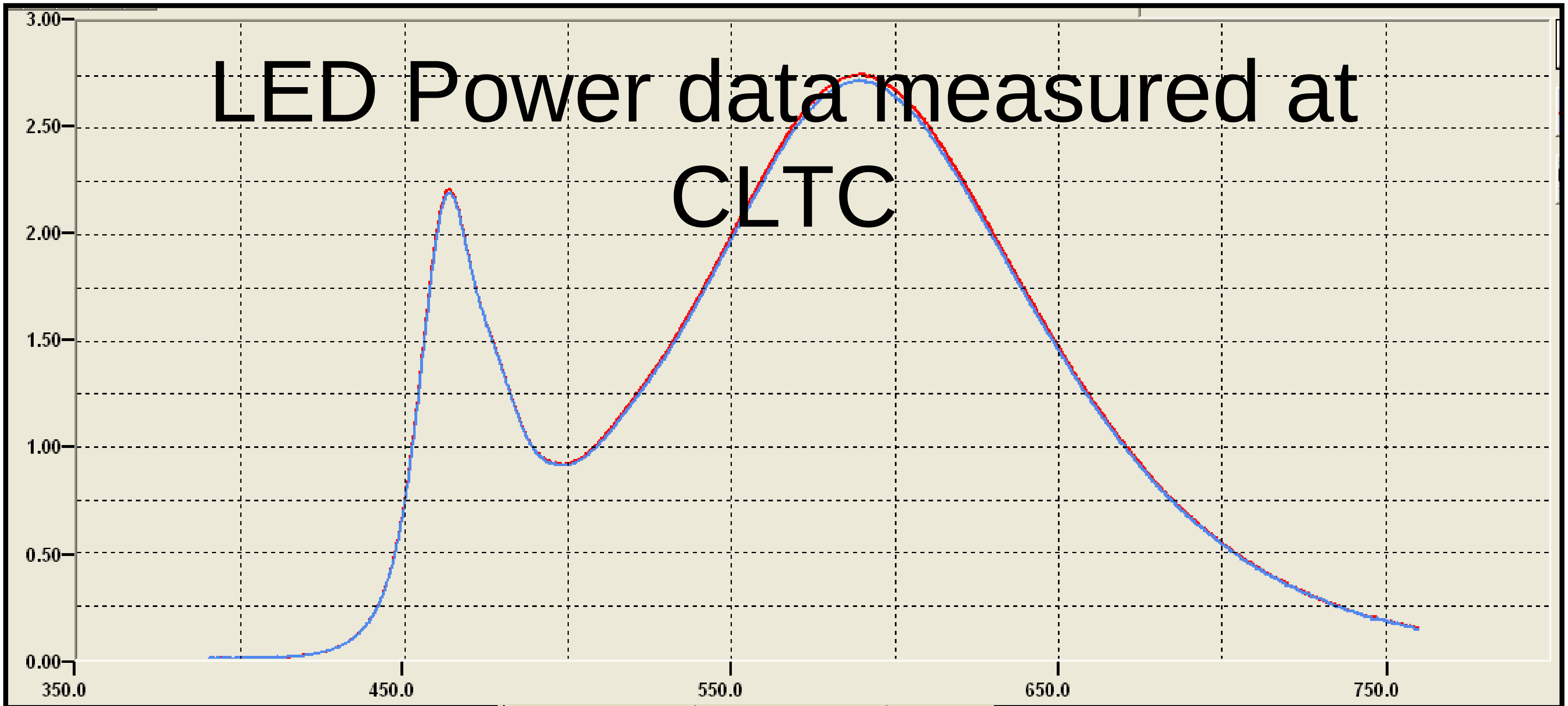
Right Side Avg:92

Both Sides Avg: 97.5

Luminance Averages: cd/m^2

Standard auto focus picture of fluorescents showing difference in fluorescent flux levels

LED Power data measured at CLTC



R (mW)	444.565	440.105
L (lumen)	145.829	144.271
Chrom x	0.4130	0.4127
Chrom y	0.4025	0.4023
Chrom u	0.2358	0.2357
Chrom v	0.3448	0.3447
CCT (K)	3431	3435
Wpeak (nm)	590.50	588.75
FWHM (nm)	126.75	126.77
Wcenter (nm)	590.48	590.41
Wcentroid (nm)	582.10	582.02
Wdominant (nm)	492.36	492.25
Purity (%)	8.38	8.47
CRI: Ra	77.5	77.4
Corr Coeff	0.00347	0.00341
Correlation	HIGH	HIGH

CRI = 77.5

4.25 W

34.2 L/W

Appendix B-3
CLTC Key Points

Northern California Grocery Store: Fluorescent vs. LED comparison key Points:

Setup:

- Nikon Coolpix 5400 digital camera with fish eye lens used for photographs in luminance maps.
- Photolux 2.0 software used to analyze digital images to give luminance maps.
- Illuminance measurements taken with CL-200 Konica Minolta Chroma Meter.
- CCT measurements taken with CL-200 Konica Minolta Chroma Meter.
- Illuminance measurements taken at 14th door from right side of cases.
- Measurements taken 7.5 inches from shelf level on each shelf.
- Luminance maps taken 27.5 inches away from door and 30 inches from shelf.
- Center door in each map is used for luminance map comparison

Illuminance Summary:

- CCT Fluorescents: 3208
- CCT LED: 3543
- Illuminance values (foot candles) in summary table.
  - Left side average Fluorescent: 233
  - Left side Ave LED: 164.4
  - **Left Fluorescent is 42% higher than LED**
  - Right side average Fluorescent: 198.4
  - Right side Ave LED: 166.2
  - **Right Fluorescent is 19% higher than LED**
  - Middle side average Fluorescent: 128
  - Middle side Ave LED: 56.4
  - **Middle Fluorescent is 127% higher than LED**
- Left and right foot candles measurements are comparable in LED and Fluorescent, but middle values are more than double in center compared to LED.

Luminance Summary: (cd/m^2 = nits)

- Summary table included.
- Fluorescent lamps have higher light levels: **129** average compared to **90** LED average for entire door.
- Fluorescent luminance maps have better uniformity on **average**. The fluorescent center average is **95** nits and the entire door average is **129** nits. That is **36%** more light on the entire fluorescent door compared to the middle. Compared to **52** nits in the center compared to **90** nits on the entire door. The entire door is **73%** brighter than the center.
- LED has more consistency in luminance values from door to door. **Max-min** ratio for LED center is: **1.7:1**, compared to Fluorescent max min ratio of: **3.25:1.**
- Some Fluorescent doors are very dim, while other fluorescent doors are quite brite. Compare door 11 with a fluorescent nit value of 268 nits and the LED luminance value of 111. That is a peek value for both lighting technologies, proving that the reflection off the food is very high, but the large peak on the right

side of the door shows a problem with the fluorescent lamp. The lamp appears to be over driven and producing too much light and causing glare on the customer.

- Door 17 has a fluorescent nit value of 74, which is lower than any LED door. Proving that that particular fluorescent door has lamps that are under driven and could be a problem.

Entire Door	Fluorescent	LED
Max	268	111
Min	74	79
Average	**129.33**	**90.20**

- Max fluorescent value is more than double the max of LED, yet average is only 43% more and Minimum value of fluorescent is actually lower than LED minimum.

Appendix C
Calculations

Appendix C-1
System Efficacy

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

Light and Power

Case	(1) Average Power (kW)	(2) Luminance cd/m^2	(3) Illuminance (fc)
T8 Fluorescent - Base Case	2.25	134	186
LED Light Bar - Test Case	1.29	90	129
Test Case as a % of Base Case:	57%	67%	69%
% Reduction	43%	33%	31%

(1) Power input for set of test cases.
(2) Luminance (brightness) measured by CTLC for several doors (average).
(3) Illuminance (light levels) measured by CTLC for "14th Freezer Door"

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	62.6	5,200	83.1
LED Light Bar, (1) 4' length	21.6	576	26.7
Test Case as a % of Base Case:	57%		32%

Efficacy (Based on Rated Data)

Case	(7) Power Input (W per unit)	Initial Lumens (lm/unit)	Efficacy (lm/W)
T8 Fluorescent, (1) 5' lamp	58.0	5,200	89.7
LED Light Bar, (1) 4' length	19.2	576	30.0
Test Case as a % of Base Case:	55%		33%

(4) Power inputs based on measured data.
(5) Rated initial lumens from manufacturer product sheets, LED Power & for SLI F58T8
(6) Calculated as noted: initial lumens / input wattage
(7) LED power input = rated 16W/bar; 80% efficient driver per manufacturer
(7) Fluorescent systems based on rating for 2L Advance ICN-2S54 @116W.

PG&E Emerging Technology Study: Refrigerator Case LED Lighting
Grocery Store (San Francisco Bay Area)
CLTC Data, values modified for "Door 32"

Luminance results (cd/m^2)

	Fluorescent				LED			
	Left	Center	Right	Entire Door	Left	Center	Right	Entire Door
Door 2	127	80	126	112	105	54	98	88
Door 5	148	82	130	120	103	46	92	79
Door 8	142	98	127	123	106	49	106	89
Door 11	183	192	433	268	130	71	127	111
Door 14	87	65	87	78	104	42	90	81
Door 17	61	59	98	74	117	44	98	88
Door 20	257	119	155	183	102	52	120	94
Door 23	141	92	118	116	94	51	102	85
Door 26	161	113	249	180	107	54	99	86
Door 29	130	113	161	137	127	58	117	101
Door 32 average	84	67	86.5	80.5				
Door 32 run 1	85	74	87	85				
Door 32 run 2	83	60	86	76				
Max	257	192	433	268	130	71	127	111
Min	61	59	86	74	94	42	90	79
Average	**138.27**	**98.18**	**160.95**	**133.77**	**109.50**	**52.10**	**104.90**	**90.20**
Max/Min	4.2	3.3	5.0	3.6	1.4	1.7	1.4	1.4

Phone: 415.434.2600

Appendix C-2
Project Economics

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

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, including (3) T8 lamps located in endcap cases that were not replaced as a part of this project. Both the "lighting retrofit" and the "heat" calculations exclude the effect of the endcap lighting as it remains a constant lighting load of 96W. Greater savings could be anticipated if these systems had likewise been changed.

Lighting Retrofit Energy Savings

	(1) Case Lighting Annual Hours (hrs/yr)	(2) Average Power (kW)	(3) Lighting Energy (kWh/yr)	% reduction in kWh from base case
T8 Fluorescent	6,205	2.25	13,986	
LED Light Bar	6,205	1.29	8,029	
		0.96	5,957	43%

Electric Demand Savings:	0.96	kW
Electric Energy Savings:	5,957	kWh/yr

Heat Calculations

	(2) Average Power (kW)	(4) Output-Input Ratio	(5) Power to Source (kW)	(6) Total Source Heat (btu/hr)
T8 Fluorescent	2.25	87%	1.96	6,689
LED Light Bar	1.29	80%	1.04	3,550
			0.92	3,140

Compressor Efficiency:	2.0	COP (7)
Heat Load Reduction:	3,140	btu/hr
Case Lighting Operating Hours:	6,205	hrs/yr (1)
Electric Demand Savings:	0.46	kW (8)
Electric Energy Savings:	2,854	kWh/yr (3)

Energy Savings Summary

Lighting Demand Savings:	**0.96**	**kW**	
Lighting Energy Savings:	**5,957**	**kWh/yr**	
Compressor Demand Savings:	**0.46**	**kW**	
Compressor Energy Savings:	**2,854**	**kWh/yr**	
Total Demand Savings:	**1.42**	**kW**	
Total Energy Savings:	**8,811**	**kWh/yr**	
Energy Rate:	**$ 0.13196**	**/kWh**	per PG&E rate calc on pge.com for E-19S
Annual Dollar Savings, Energy:	**$ 1,162.70**	**/yr.**	
Annual Avoided Maint. Cost:	**$ 375.33**	**/yr.**	per avoided cost calculation
Total Annual Savings:	**$ 1,538.03**	**/yr.**	

Notes:

1) Annual operating hours of the refrigeration case lighting system is 17 hrs/day * 365 days/yr = 6,205 hrs/yr. This operating schedule is supported by the power data taken before and after LED installation.
2) Average demand taken from power logging data.
3) Energy Savings (kWh/yr) = Demand Savings (kW) * Annual Operating Hours (hrs/yr)
4) Ratio = Ouput Power / Input Power. It is assumed that 16W are used by a fluorescent ballast per IES 9th Edition. Also, it is assumed that 1.2W are consumed by the LED driver per an email from the manufacturer.
5) Power to Source (kW) = Average Input Power (kW) * Output-Input Ratio.
6) Source Heat (btu/hr) = Power to Source (kW) * Percent Heat Energy * 3,413 (btu/kW)
7) Typical low-temperature refrigeration coefficient of performance (COP) taken from Copeland product literature.
8) Electric demand savings for refrigeration is based on average COP (see note 7).

Phone: 415.434.2600

Pacific Gas and Electric Company

Bundled Commercial/General Service Electric Rates at a Glance

Rates Effective:
September 1, 2006, to Present

Rate Schedule	Customer Charge	Optional Meter Data Access Charge	Season	Time-of-Use Period	Demand Charge (per kW)			Time-of-Use Period	Total Energy Charge[1/] (per kWh)				"Average" Total Rate[2/] (per kWh)
A-1 Basic general service rate. Generally optimal rate for customers with low electric use and low load factors, with most usage during PG&E's peak and partial peak TOU periods.	Single Phase Service per meter/day =$0.26612 Polyphase Service per meter/day =$0.39425		**Summer**						$0.18349				$0.16727
			Winter						$0.13456				
A-6 Rates vary according to the time of day electricity is used. Typically, the A-6 rate benefits customers who use a significant percentage of their electricity during the off peak period.	Single phase service per meter/day =$0.26612; Polyphase service per meter/day =$0.39425. Plus Meter charge =$0.20107per day for A6 or A6X; =$0.05914 per day for A6W[3/]		**Summer**					On peak	$0.31618				$0.13918
								Part Peak	$0.15738				
								Off Peak	$0.09511				
			Winter					Part Peak	$0.13915				
								Off Peak	$0.10376				
					Secondary	**Primary**	**Transmission**		**Secondary**	**Primary**	**Transmission**		
A-10 **(Non-FTA Rates)** Customers with high electric use and medium to high load factors generally benefit under Schedule A-10. Part of a customer's bill varies according to the customer's maximum monthly electric demand.	$3.05215 per meter per day	$0.98563 per meter per day	**Summer**		$10.83	$10.22	$7.25		$0.12410	$0.12446	$0.11701		$0.14299
			Winter		$5.64	$5.14	$3.31		$0.09423	$0.09381	$0.08998		
A-10 **(FTA Rates)** Customers with high electric use and medium to high load factors generally benefit under Schedule A-10. Part of a customer's bill varies according to the customer's maximum monthly electric demand.			**Summer**		$10.83	$10.22	$7.25		$0.12899	$0.12935	$0.12190		
			Winter		$5.64	$5.14	$3.31		$0.09912	$0.09870	$0.09487		
A-10 TOU **(Non-FTA Rates)** Customers with high electric use and medium to high load factors generally benefit under Schedule A-10 TOU. Part of a customer's bill varies according to the customer's maximum monthly electric demand.			**Summer**		$10.83	$10.22	$7.25	Peak	$0.14300	$0.14280	$0.13619		**Secondary** $0.14305
								Part-Peak	$0.13185	$0.13275	$0.12566		
								Off-Peak	$0.10897	$0.10937	$0.10124		
			Winter		$5.64	$5.14	$3.31	Part-Peak	$0.10258	$0.10163	$0.09822		**Primary** $0.13678
								Off-Peak	$0.08596	$0.08606	$0.08182		
A-10 TOU **(FTA Rates)** Customers with high electric use and medium to high load factors generally benefit under Schedule A-10 TOU. Part of a customer's bill varies according to the customer's maximum monthly electric demand.			**Summer**		$10.83	$10.22	$7.25	Peak	$0.14789	$0.14769	$0.14108		
								Part-Peak	$0.13674	$0.13764	$0.13055		**Transmission** $0.12490
								Off-Peak	$0.11386	$0.11426	$0.10613		
			Winter		$5.64	$5.14	$3.31	Part-Peak	$0.10747	$0.10652	$0.10311		
								Off-Peak	$0.09085	$0.09095	$0.08671		
E-19 **(Non-FTA Rates)** Offers demand-metered time-of-use (TOU) service. Customers likely to benefit have high electric use and high load factors and are able to use significant percentages of their electricity during the off-peak period. There are **optional** (E19V, E19 X and E19W) versions below 500 kW as well as E19 **mandatory** which applies to accounts with demands between 500 and 1,000 kW. See tariff for rate limiter, power factor, nonfirm.	Meter charge: =$3.22956/day for E19 V or X; =$3.08763/day for E19W[3/]; =$9.03491/day for E19S mandatory; =$13.14168/day for E19P mandatory; =$34.18086/day for E19T mandatory	$0.98563 per meter per day	**Summer**	Max. Peak	$14.72	$10.38	$10.46	Peak	$0.13799	$0.12912	$0.09893		**Secondary** $0.13196
				Part Peak	$3.51	$2.38	$2.42	Part Peak	$0.10016	$0.09652	$0.08980		
				Maximum	$7.03	$5.10	$3.58	Off Peak	$0.07097	$0.06909	$0.06864		
			Winter	Part Peak	$1.83	$0.75	$0.00	Part Peak	$0.09182	$0.08719	$0.08597		
				Maximum	$7.03	$5.10	$3.58	Off Peak	$0.07442	$0.07228	$0.07175		**Primary** $0.11630
E-19 **(FTA Rates)** Offers demand-metered time-of-use (TOU) service. Customers likely to benefit have high electric use and high load factors and are able to use significant percentages of their electricity during the off-peak period. There are **optional** (E19V, E19 X and E19W) versions below 500 kW as well as E19 **mandatory** which applies to accounts with demands between 500 and 1,000 kW. See tariff for rate limiter, power factor.			**Summer**	Max. Peak	$14.72	$10.38	$10.46	Peak	$0.14288	$0.13401	$0.10382		
				Part Peak	$3.51	$2.38	$2.42	Part Peak	$0.10505	$0.10141	$0.09469		
				Maximum	$7.03	$5.10	$3.58	Off Peak	$0.07586	$0.07398	$0.07353		**Transmission** $0.10818
			Winter	Part Peak	$1.83	$0.75	$0.00	Part Peak	$0.09671	$0.09208	$0.09086		
				Maximum	$7.03	$5.10	$3.58	Off Peak	$0.07931	$0.07717	$0.07664		

[1/] Legislated 10% reduction on bill for A-1 and A-6 customers (and some A-10 customers) was discontinued effective January 1, 2006.

[2/] Average rates based on estimated forecast. Average rates provided only for general reference, and individual customer's average rate will depend on its applicable kW, kWh, and TOU data.

[3/] Effective May 1, 2006, the voluntary TOU one time reprogramming charge of $87 if there is a TOU meter already present, and one time $443 meter installation charge if there is no TOU meter, were eliminated.
The lower daily TOU meter charge continues to apply to customers who were on Rate W as of May 1, 2006. Rate X applies to all other customers.

Note: **Summer** Season: May-October **Winter** Season: November-April

This table provided for comparative purposes only. See current tariffs for full information regarding rates, application, eligibility and additional options.

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:	60	for a 30-door installation
Feet/Unit:	4	
Total Feet:	240	
$/Foot:	$ 25.00	PG&E's Discussions with LED Power (Current Market)
Material Cost:	$ 6,000.00	for $192/door LED & $8/door for driver.
	Labor:	
Hours/Job:	20	
# of Jobs:	1	Based on time required for sample store, 30 doors.
$/Hour:	$ 62.60	Means Electrical Cost Data Manual for 2006
City Mod:	1.389	Means Electrical Cost Data Manual for 2006 (Oakland)
Labor Cost:	$ 1,739.03	
Total Cost:	$ 7,739.03	

Mature Market

	LED Bars:	Notes:
Quantity:	60	for a 30-door installation
Feet/Unit:	4	
Total Feet:	240	
$/Foot:	$ 20.83	PG&E's Discussions with LED Power (Current Market)
Material Cost	$ 4,999.20	for $160/door LED & $6.75/door for driver.
	Labor:	
Hours/Job:	20	
# of Jobs:	1	Based on time required for sample store, 30 doors.
$/Hour:	$ 62.60	Means Electrical Cost Data Manual for 2006
City Mod:	1.389	Means Electrical Cost Data Manual for 2006 (Oakland)
Labor Cost:	$ 1,739.03	
Total Cost:	$ 6,738.23	

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 $ 1,162.70 /yr	**Simple Payback Period, Current Market** **6.7 years**	Annual Energy Savings $ 1,162.70 /yr	**Simple Payback Period, Mature Market** **5.8 years**
Total Annual Savings $ 1,538.03 /yr	**Payback Period w/Avoided Cost, Current Market** **5 years**	Annual Savings $ 1,538.03 /yr	**Payback Period w/Avoided Cost, Mature Market** **4.4 years**

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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 3 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)
a	F58T8	Lamp	15,000	41.4%	0.089	$ 7.74	$ 10.99	$ 18.73	$ 22.48	3.33	$ 74.92	$ 9.30
b	Advance ICN-2S54	ballast	140,160	4.4%	0.851	$ 73.99	$ 46.99	$ 120.98	$ 72.59	0.36	$ 25.89	$ 3.21
	TOTAL FLUORESCENT:										**$ 100.81**	**$ 12.51**
c	LED light bar/door	unit	50,000	12.4%	0.000	$ -	$ -	$ -	$ -	1.00	**$ -**	**$ -**

INITIAL MAINTENANCE SAVINGS, NET ANNUAL SAVINGS FOR LED: $ 12.51

(1) Assume Rated lamp life at 3 Hrs/Start per industry standard rating; ballast and LED system life of 50,000 hours per manufacturer. 30 doors: $ 375.33
(2) Annual failure rate = Annual operating hours / expected life. Assume operating hours to be: 6,205 /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 $ 86.95 /hr. (Means Electrical 2006 for Electrician; City modifier Oakland, CA.)
(5) Materials cost for existing & proposed or similar types per on-line ordering, www.bulbs.com
(6) For fluorescent system, total cost per door is based on 36 existing lamps per 30 doors and one fluorescent ballast per two lamps (18 ballasts per 30 doors).