Pacific Gas and Electric Company

Emerging Technologies Program

Application Assessment Report #0723

LED Lighting in Reach-In Freezer Cases: Retail Sector

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Table of Contents

Appendices

Table of Tables

Table of Figures

Preface

EMCOR Energy Services, under contract to Pacific Gas & Electric Company (PG&E), conducted this Emerging Technologies project at the San Miguel Market located in Stockton, California. This study aims to assist PG&E with the evaluation of the application of LED technology to refrigerated case lighting in the grocery retail sector.

This Emerging Technologies demonstration project was performed as a part of the PG&E's Customer Energy Efficiency (CEE) Program, part of PG&E's commitment to meeting new demand growth through energy efficiency by providing technical assistance directly to electric service customers.

EMCOR Energy Services of San Francisco, California, prepared this document for PG&E under the CEE Program. The PG&E Emerging Technologies Program Lead is Lee Cooper. The PG&E Project Manager for this project is Daryl DeJean.

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1 Executive Summary

This report summarizes the installation and assessment of light emitting diode (LED) luminaires at a retail grocery store, the San Miguel Market, in Stockton, California. Relying primarily on field testing, the project team conducted photometric and power measurements, as well as employee satisfaction surveys and economic payback calculations.[1] This application assessment study was designed to verify the brightness and quality of light currently achievable with LED lighting systems in order to aid the acceleration of their mainstream adoption in the grocery store end-use.

The baseline equipment for this study was the ***linear fluorescent lighting providing display illumination for a 3-door reach-in freezer case***. The replacement can be summarized as follows and detailed information can be found in Section 4.2.

- **Baseline linear fluorescent lighting system**
  Four linear 5' F58T8 fluorescent lamps powered by one 2-lamp solid-state ballast.[2]
- **Replacement LED lighting system**
  Four 5' LED light bars (comprised of 2 center modules and 2 side modules) powered by one electronic driver.

Results of the photometric field measurements are tabulated in Table 1-1. This study confirms general trends previously reported on the application of LED lighting systems: illuminance levels are reduced; however, uniformity, in terms of illuminance and luminance, was maintained or improved with replacement LED luminaires.

Table 1-1 Summary of Photometric Measurements

	Average[3]	Maximum to Minimum Ratio	Average to Minimum Ratio
Luminance [cd/m^2]			
Fluorescent	294.6	3.5:1	2.1:1
LED	215.3	2.1:1	1.7:1
Δ (%)	26.9%	-	-
Illuminance [fc]			
Fluorescent	163.7	4.1:1	2.3:1
LED	106.6	2.7:1	1.8:1
Δ (%)	34.9%	-	-

1 Throughout this report, “retailer”, “employee”, or “project host” refers to the host site (who may otherwise be referred to as a customer of PG&E’s electricity service). “Customer” will refer only to customers of the host facility.
2 See Section 7.1 for a discussion of irregular baseline lamp and ballast configuration.
3 See Section 7.2.1 for a characterization of data sets.

Electric demand, measured before and after project installation, was used to quantify energy savings resulting from installation of the LED lighting systems. Measurements indicate that LED luminaires reduced the overall electric demand of the system by approximately 41.8 percent. Approximately 66% of the total demand savings was due to lighting load reduction, while about 33% of the savings was realized by reductions in the refrigeration load. The combined annual lighting energy savings for these projects were 705 kWh/yr for the entire 3-door case.

Table 1-2 Summary of Electric Demand and Annual Energy Savings (per Case and per Door)

	Lighting System [kW]	Refrigeration System [kW]	Total [kW]	Annual Energy Consumption [kWh/yr]
Freezer Case				
Fluorescent	0.186	0.094	0.280	1,686
LED	0.108	0.055	0.163	981
Δ	0.078	0.039	0.117	705
Δ (%)	41.9%	41.5%	41.8%	-
Door				
Fluorescent	0.062	0.031	0.093	560
LED	0.036	0.019	0.055	331
Δ	0.026	0.012	0.038	229
Δ (%)	41.9%	38.7%	40.9%	-

The costs of electricity and electrical demand were calculated based on the time-based occurrence of project savings using PG&E's E-19S rate, typical for large grocery stores. Additionally, LED luminaires have been shown to demonstrate a much greater effective useful life than fluorescent or other conventional lighting systems.[4] This results in fewer equipment replacements and lower maintenance costs. More than two cycles of fluorescent lamp replacements will be avoided during the expected life of the LED system. Annual energy use and maintenance cost savings are detailed in the table below.

Table 1-3 Annual Energy and Maintenance Cost Savings

Annual Cost Savings				Simple Payback Period (yrs)	
Energy ($/yr)	Maint. ($/yr)	Total ($/yr)	Project Cost	Energy Savings Only	Energy and Maintenance Savings
$81.43	$114.24	$195.67	$879.48	10.8	4.5

This measure is technically feasible but is not cost-effective with current market conditions. When maintenance savings are included, the simple payback period falls within the system EUL of 8.3 years.

[4] (Building Technologies Program February 2007)

LED lighting is a rapidly advancing technology. It is widely anticipated that on-going improvements in materials science, thermal efficiencies, optical design, and installation methods will lead to continuing price reductions and higher energy savings. Similar developments in the marketplace are also improve cost-effectiveness. Moreover, in the near term, utility incentive programs can reduce initial cost to the retailer and potentially accelerate market adoption of this promising energy efficient technology.

The results of this study do not reveal major progression, in terms of the ratio between demand savings and illuminance level reduction, from two previous LED freezer case lighting system Emerging Technology Studies application assessment studies under the PG&E Emerging Technologies Program (Application Assessment Reports #0608 and #0722). Differences in load reduction potential, system operating hours, utility rate structure, and cost of implementation contributed to variances in the simple payback periods associated with these studies.

Table 1-4 Comparison with Previous Application Assessment Studies

Application Assessment # /Year	Lighting System	Lighting System Efficacy [lm/W][5, 6]	Average Electric Demand (Lighting) [W/door]	Average Measured Illuminance [fc] (Max. to Min. Ratio)	Installation Cost [$] (Payback [yr])
#0608/06-07	5' 58W HO T8 fluorescent	83.1	75	186 (3.0:1)	
	LED Power Piranha	26.7	43	129 (5.6:1)	$55,566 (10.3)
	Δ (%)	-	43%	31%	
#0722/07-08	5' 40W T8 fluorescent	84.4	59	78 (1.2:1)	
	LED Power Green Power	49.2 *(30.6)*[7]	28	45 (1.9:1)	$7,739 (5.0)
	Δ (%)	-	53%	42%	
#0723/08-09	5' 58W T8 fluorescent	-	62	164 (4.1:1)	
	Philips Affinium LFM 200	-	36	107 (2.7:1)	$879 (4.3)
	Δ (%)	-	42%	35%	

These results, essentially spanning a 3-year period, tend to indicate that projected improvements in product design and market stabilization are slow to be realized in actual field conditions. Importantly, however, this study employs a more comprehensive photometric testing methodology than past studies, conceptualized by the DOE; due to the fundamental difference in lighting technology, and the uncertainty introduced into the market by a lack of standardization amongst manufacturers, improvements to evaluation and comparison methods are also expected to aid in establishing performance trends. Specifically, the development of uniform testing protocols and standard metrics particular to LED lighting systems would accelerate progress in this field.[8]

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5 Efficacy ratings based on measure electric demand and manufacturer specifications of lumen output.

6 Efficacy rating for Phillips Affinium modules unavailable at time of report issuance.

7 Efficacy rating from independent laboratory testing data.

8 One such example of anticipated standardization is specifically cited, although ANSI, IESNA, and other institutions for standardization are also rapidly supplying improvement. See “Recommendations for Testing and Evaluating Luminaires for Refrigerated and Freezer Display Cases.” ASSIST. Lighting Research Center at the Rensselaer Polytechnic Institute. Volume 5, Issue 1, November 2008.

2 Project Background

2.1 LED Technology Overview

A light emitting diode (LED) is a semiconductor diode that emits light from a p-n junction when electric current is applied in the forward direction. A p-n junction is formed when a P-type semi-conductor (a semi-conductor doped to increase the amount of positive free charge carriers) is connected to a N-type semiconductor (a semi-conductor doped to increase the amount negative free charge carriers). The wavelength of the emitted light, and therefore its perceived color, depends on the semi-conductor materials of which the p-n junction consists. Additionally, the lens of the LED can be coated in order to further effect the wavelength of light emitted.

Although developed in the 1960s, application of LEDs has been limited due to color and performance restrictions imposed by the availability of primary usable elements within the diode: initially red only. LEDs developed in the 1980s 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 consequently of white LED sources (white light from LEDs is produced by combining red, green, and blue LED sources or by coating a blue LED with yellow phosphor). This was a breakthrough that offered a much broader range of applications than previously available. Due to continuous research and development in the technologies of semiconductors and optics, LEDs are now well known as efficient lighting technologies. Recent advances in the technology's materials science have also extended LED expected life, brightness, and efficacy. Today's technology affords a burgeoning array of LED applications, many of which are gaining acceptance in the marketplace.

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 freezer grocery cases. The Lighting Research Center at Rensselaer Polytechnic Institute (RPI) published a study on this application, "Refrigerated Display Case Lighting with LEDs."[9] This 2002 laboratory study illustrates a strong customer preference for products 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.

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[9] Raghavan, Ramesh and Narendran, Nadarajah, 2002

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."[10] "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."

In July 2008, the Sacramento Municipal Utility District released a technology evaluation report, "LED Freezer Case Lighting Systems" through the Customer Advanced Technologies Program. LED lighting systems were tested and evaluated in freezer case lighting applications. In this study, occupancy sensors were used to control lighting system operation. The report indicated that replacement system was acceptable to the majority of surveyed customers, and further, demonstrated reduced lighting and refrigeration use with no measurable effects upon product sales.

Finally, reports have previously been completed for LED freezer case lighting retrofits under the PG&E Emerging Technologies Program at a Northern California grocery store (Application Assessment Report #0608), and at a merchandise wholesale retail facility (Application Assessment Report #0722). Table 1-4 summarizes results from the two previously completed freezer case lighting studies, and the results gathered from this report. Differences in load reduction potential, system operating hours, utility rate structure, and cost of implementation contributed to variances in the simple payback periods associated with these studies.

The LED systems used in the first study provided less light output per watt consumed (lumens/watt) than the systems used in the second study. The manufacturer for the current study, Philips, has provided neither independent test data nor manufacturer's claims related to lumen output to the authors, therefore, estimates of system efficacy could not be established for the current case. The replacement LED system evaluated in this study afforded reductions in power and average illuminance comparable to the replacement system evaluated in the first of the three studies.

2.3 Current Technical and Market Status

Virtually all freezer 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. LED sources, conversely, are designed to operate at lower ambient temperatures, driving efficacy to levels provided by fluorescents in the freezer environment.

LED optics is directional as compared to the omni-directional distribution provided by fluorescent lamps. The directional optics are suited to the case lighting environment where

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[10] Narendran, Brons, Taylor, 2006

the primary target is the merchandize rather than the surrounding door case mullion, which is well-lit in typical fluorescent applications.

LED assemblies for use in freezer cases are currently available in the marketplace. Several systems, including General Electric's “Lumination,” and American Bright Lighting's “Simpletube,” for example, are designed specifically for use in the low temperature, retail display case market. Several of the available product lines can be controlled with dimming and motion control devices (occupancy sensors) 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. In mid-2008, 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. Hussmann Corporation, a manufacturer of freezer case systems, has introduced their “Always*Bright LED Lighting System” as a factory option for medium temperature cases and reach-in cases. Hussman also provides retrofit lighting systems for existing cases.

The Philips Affinium LFM 200 LED modules were selected for testing in this study. Product specifications are available in Appendix D-2.

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. Application assessment studies, such as this serve to measure, verify, analyze, and document the potential energy savings and electric demand reduction of specific technologies and applications in different market segments.

This study focused on the following objectives in order to gauge the current feasibility and performance of the application of LED light sources to the grocery store environment, categorized as the Grocery (GRO) end-use in the Database for Energy Efficient Resources (DEER):

- The quantitative comparison of the luminance, illuminance, and correlated color temperature measured in the field application of LED luminaires and baseline lighting systems in a 3-door, low temperature, refrigerated case.
- The quantification of potential energy savings. This study incorporated data logs from isolated lighting circuits to determine the level of demand and energy savings currently achievable by LED luminaires.
- The solicitation of feedback from store management and personnel regarding the project implementation and outcome.

4 Experimental Design and Procedure

4.1 Project Background and Timeline

Prior to this study, PG&E had identified LED sources as an emerging technology application for freezer case lighting, developed test objectives and conditions, and identified a project host, a grocery store in Northern California, to participate in the study. PG&E drafted a scope of work outlining the basic steps required for a field evaluation of this technology, and the project team drafted a test protocol to be used in planning for and conducting the field-testing of the baseline and LED lighting systems.[11]

This application assessment study was designed to measure the performance of a lighting system in a freezer case lighting application. PG&E worked with the project host to identify the lighting system and application: ***linear fluorescent lighting providing display lighting for one 3-door reach-in freezer case.*** Information about the two lighting systems, baseline and replacement LED, is summarized below and detailed information can be found in Section 4.2.

- **Baseline linear fluorescent lighting system**
  Four linear 5' F58T8 fluorescent lamps powered by one 2-lamp solid-state ballast.[12]

- **Replacement LED lighting system**
  Four 5' LED light bars (comprised of 2 center modules and 2 side modules) powered by one electronic driver.

Photographs of the baseline and LED lighting systems are shown in Figure 4-1 and Figure 4-2, respectively.

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[11] Sections 4.3, 4.4, and 4.5 provide more information and the full test protocol can be found in Appendix A.

[12] See Section 7.1 for a discussion of baseline lamp and ballast configuration.

Figure 4-1 Baseline Lighting (T8 Fluorescent Lamps)

Figure 4-2 LED Lighting (LED Light Bars)

The following are key dates and milestones of the project:

October 23, 2007
Start-up meeting. PG&E, project host, and project evaluation team were present to identify test stores and discuss project parameters.

October 30, 2007
PG&E, project host, and project evaluation team identifies test areas within the previously identified test stores.

June 6, 2008
Baseline fluorescent lamps replaced and burn-in period initiated (see Section 4.2 below).

June 12, 2008
Baseline photometric testing performed and electric demand data logger installed to record baseline power measurements for baseline fluorescent lighting.

July 2, 2008
Baseline photographs taken to visually document baseline conditions.

July 23, 2008
Replacement LED lighting systems installed.

August 7, 2008
Photometric testing of LED lighting system performed and electric demand data logger installed to record power measurements for LED lighting system.

September 18, 2008
Electric demand data logger disconnected and power measurements collected.

November 10, 2008
Project host provided with Customer Feedback Survey.

4.2 Product Information and Installation

The baseline lighting system was comprised of four linear 5' F58T8 fluorescent lamps powered by one 2-lamp solid-state ballast.[13]

In typical three-door freezer cases, lamps are installed vertically along the interior of each doorframe. Additionally, a distinction is made between lamps located on center mullions (the part of the case frame which divides two doors) and on end caps (the corner framing of the three-door case). Ballasts are generally installed below the case within insulated housing to prevent unnecessary heat gain to the freezer compartment. Cases are generally served by a

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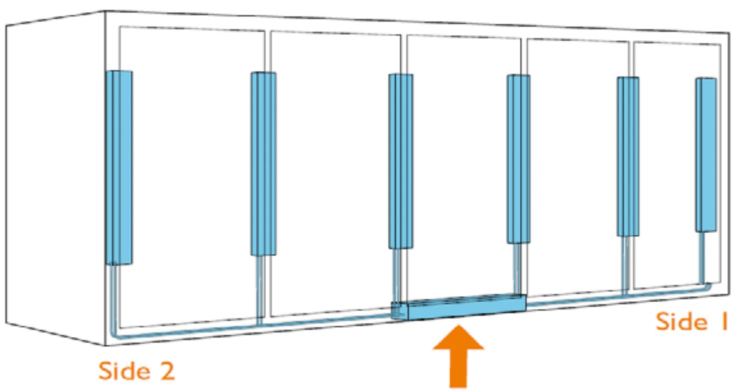
13 According to the freezer case manufacturer, four lamps should have been powered by two 2-lamp ballasts. Nonetheless, only one 2-lamp ballast was noted to be installed; power measurements support this observation, and the irregular configuration of the baseline lighting system bears relevance to demand savings calculations presented in Section 6.1.2 and is further discussed in Section 7.1.

system of refrigeration compressors, which are located in a remote indoor service space near the main electrical distribution.

Prototype LED light bar luminaires, Affinium LED LFM 200 modules, were provided and installed by Philips. Four 5' LED light bars were powered by one electronic driver. A similar distinction is drawn between center and end cap luminaires, and, since lamps are wired either from the top or the bottom of the light bars, modules are also denoted by side so as to ensure the proper optical arrangement of the light bar. Figure 4-3 illustrates the configuration of light bars and driver employed in this study; although for a 5-door rather than 3-door freezer case, the situation of the side 1 and side 2 modules and the location of the driver at the bottom of the case reflect the installation in the project.

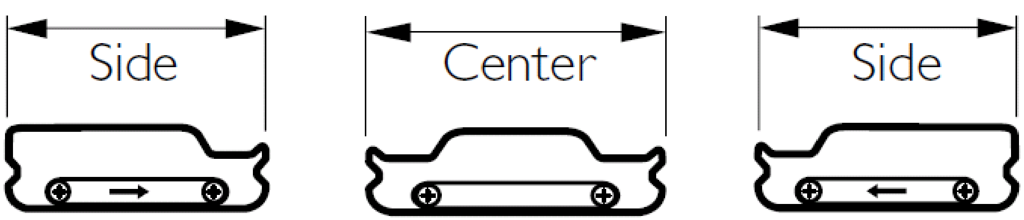
Figure 4-3 Configuration of LED lighting system with electrical connections at the bottom of the freezer



Source: Philips.

Figure 4-4 illustrates the differing optics between center and side light bars (the center light module has twice the amount of LEDs as the side modules, reflected in its input power). Detailed information for each lighting system is summarized in Table 4-1.

Figure 4-4 Optics of side and center modules



Source: Philips.

Table 4-1 Lighting System Specifications

	Baseline linear fluorescent system	Replacement LED system		
Lamp Information		Side 1	Center	Side 2
Lamp shape	T8	Light bar		
Base	Medium Bi-Pin (G13)	-		
Length (in.)	60	59		
Watts	58	15	25	15
Lamp designation	F58T8/841-CT	Affinium LED modules LFM 200		
Designation/special features	Cold temperature	Standard lighting level 700 lux		
Diameter (in.)	1	1.93	2.20	1.93
Average life (hours)	20,000	50,000		
Lamp tone	Enhanced cool	Cool white		
Color temperature (K)	4,100	5600 ± 600		
CRI	85	≥ 70		
Initial lumens	5800	-		
Mean lumens	4160	-		
Start type	Rapid start	-		
Ballast/Driver Information				
Item	Electronic ballast	LED electronic driver		
Start type	Programmed	-		
Number of lamps	2	4		
Voltage AC	120/277	100/277		
Amps AC	0.98-0.43	1.0-0.4		
Input watts	116-114	100		
Ballast designation	GE254MVPS90-D	Xitanium		
Minimum starting temperature (°F)	0	-		
Ballast factor	1.00	-		
Power factor	> 0.98	> 0.9		
Special features	Anti-striation control	-		
Light output	High	-		
Ballast family	Ultrastart	-		

4.3 Photometric Field Measurements

4.3.1 General Approach

Lighting performance was measured and assessed in terms of three main attributes: luminance, illuminance, and correlated color temperature (CCT). The Lighting Design Lab provides an online glossary of lighting terms; key terms are described below as a background to the test parameters.[14]

[14] (Lighting Design Lab n.d.)

- **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." Luminance is measured in candela per square-meter (cd/m^2).

- **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).

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

One of the requests that preceded this study was for existing fluorescent lamps to be replaced with new fluorescent lamps and to ensure they operated prior to testing (*burned in*) for at least 100 hours to stabilize the baseline condition. This adjustment to the baseline condition was intended to allow the comparison of the light output of existing and replacement light sources at the same point of depreciation, in this case as new.

The ambient light levels were considered to equally impact the baseline and the replacement lighting.

4.3.2 Measurement Locations

Based on direction from the DOE, the original testing protocol, provided in Appendix A, was modified to employ a more comprehensive methodology.

Photometric measurements were to be taken at discrete, repeatable locations on white foam core board (20" by 60") placed approximately six inches behind the glass freezer doors. For consistency between pre- and post-installation conditions, 18 points 10" apart were marked on the board (with pale-colored stickers so as not to influence light readings), yielding six rows and three columns of measurements. Measurements were performed at the same positions and from the same viewing angles in both the baseline and test case.

4.3.3 Luminance Measurements

Luminance was measured in candela per square meter (cd/m^2). Luminance readings were recorded with the sensor of the light meter aimed horizontally at a distance of 4' from the glass freezer case door.

4.3.4 Illuminance Measurements

Illuminance values for this study were recorded in footcandles (fc). Illuminance readings were performed with the sensor of the light meter aimed perpendicularly to the horizon.

4.3.5 Correlated Color Temperature Measurements

CCT measurements were recorded at the center of the foam core board and measured in Kelvin (K).

4.4 Electric Demand Measurements

An electric demand data logger was installed, pre-programmed to record voltage, current, power factor, and electric demand at 15-minute intervals. The circuit associated with the refrigerated case lighting was identified in lighting control Panel LL1 as Breaker #21.

4.5 Testing Equipment

The following monitoring equipment used in the execution of this Monitoring Plan:

- **Correlated Color Temperature Meter/Illuminance Meter**
  Konica Minolta CL-200 Chroma Meter with ±2% accuracy; last calibrated October 2007.

- **Luminance Meter**
  Konica Minolta LS-100 Spot Luminance Meter with ±2% accuracy; last calibrated October 2007.

- **Electric Demand Meter**
  DENT ElitePro Data Logger with ±0.5% accuracy typical; last calibrated April 2007.

5 Facility Information

The host facility is a grocery store located in Northern California. PG&E provides electrical service. Grocery stores in PG&E's service territory normally qualify for an E-19S time-of-use electricity rate because electric demand often falls between 500 kW and 1,000 kW. PG&E confirmed that the host facility operates on a E-19S time-of-use rate schedule.

The E-19S rate schedule is a time-of-use tariff, which means that electricity is provided at different rates depending on the time of day it is used. Based on PG&E E-19S rate schedule information, the average electricity cost during the occurrence of project savings was calculated to be $0.1155/kWh; this figure includes demand charges.[15]

[15] Please refer to Appendix C-2 for rate information and time-of-use rate calculations.

6 Project Results

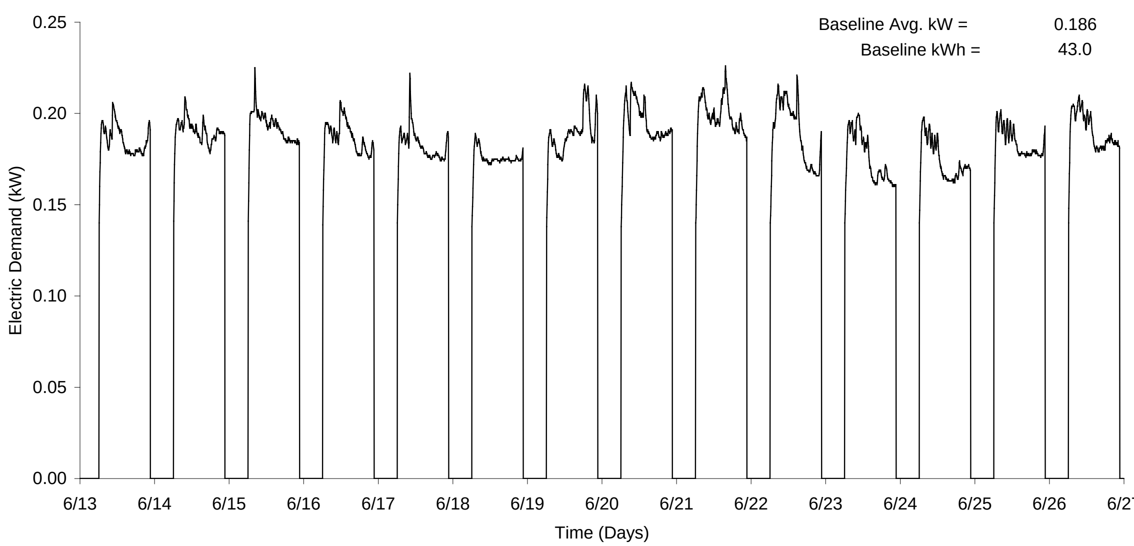
6.1 Electrical Energy and Demand Savings

Calculations of electrical energy and demand savings are based on electric demand measurements from baseline and LED luminaires.[16] Savings are calculated based on electric demand logged for the entire isolated lighting circuit.

6.1.1 Electric Demand Measurements

Figure 6-1 and Figure 6-2 show respective data from the 14-day baseline fluorescent and replacement LED testing periods during which the electric demand data logger was installed. The reduction in power demonstrates the demand savings achieved with the installation of the LED light bars; the reduction in electric demand for the entire circuit was calculated at 0.078 kW.[17]

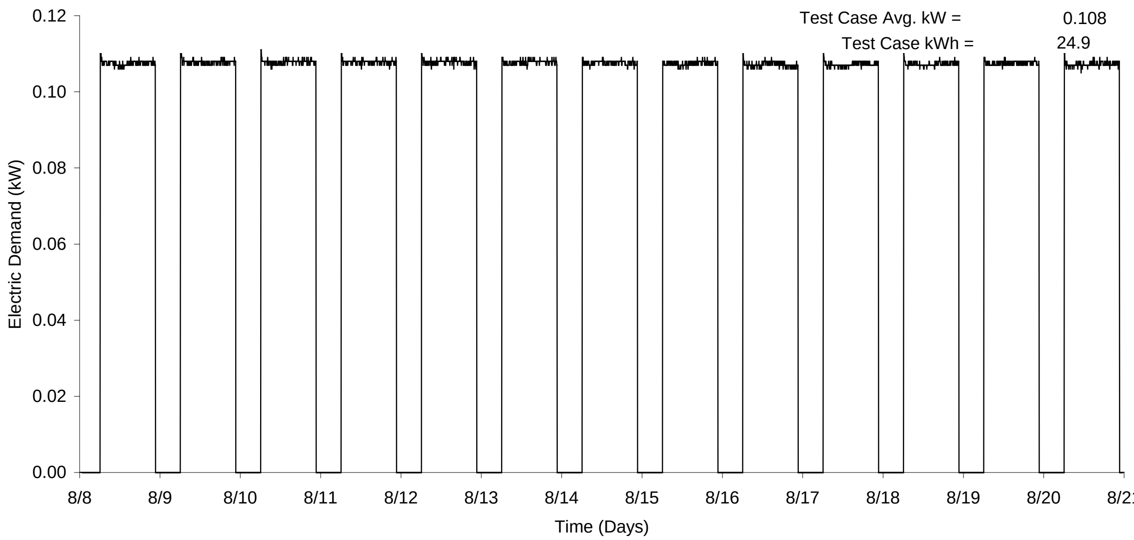
Figure 6-1 Baseline Fluorescent Lighting System Electric Demand Profile



[16] Complete electrical energy and demand savings calculations can be found in Appendix C-2.

[17] Importantly, power measurements must be considered along with the observation that four lamps were powered by only one 2-lamp ballast. Refer to Section 7.1 for further discussion.

Figure 6-2 Replacement LED Lighting System Electric Demand Profile



Also noted was a change in the variance of amplitude of the power draw; however, power management information for the LED luminaires was not available.

6.1.2 Demand Savings

The electric demand savings for the entire project were calculated at 0.117 kW. The additional 0.039 kW of savings are due to the reduction in refrigeration demand that results from the differential cooling load imposed upon the compressor by the lighting systems. The product of the reduction in heat load source (HLS) from the two lamps and the coefficient of performance (COP) of the compressor was used to calculate the total heat load reduction, as shown below:[18]

$$(1)\ HLS\ (kW) = Measured\ electric\ demand\ (kW) \times Lamp\ power\ draw\ (\%) \times Power\ to\ heat\ ratio\ (\%)$$

$$(2)\ Compressor\ COP\ (\%) = Energy\ efficiency\ ratio\ (\%) \times 3.412$$

$$(3)\ Heat\ load\ reduction\ (kW) = \left(HLS_f - HLS_l\right) \times Compressor\ COP$$

[18] In (1), lamp power draw was conservatively based on 10% ballast power draw, 90% lamp power draw; power to heat ratio for the lamp was assumed at 79% based on the IESNA Handbook, 9th Edition page 6-29. In (2), the energy efficiency ratio (EER) was assumed to be 4.9 based on compressor efficiency calculations. In (3), f and l denote the heat load source of the fluorescent and LED lighting systems, respectively.

The average measured power and calculated demand savings per fixture are summarized in Table 6-1.

Table 6-1 Project Demand Savings (kW)

System	Lighting System	Refrigeration System	Total System
Refrigerated Case			
Fluorescent	0.186	0.094	0.280
LED	0.108	0.055	0.163
Δ	0.078	0.039	0.117
Door			
Fluorescent	0.062	0.031	0.093
LED	0.036	0.019	0.055
Δ	0.026	0.012	0.038

The project host uses a lighting control system to control the lighting; the test area operates during store hours, including throughout the utility peak electricity rate period, which extends through the hours 12 pm to 6 pm. The recorded data supports the operating hours. Therefore, the demand savings for this project are coincident because they reduce the electric load during the utility peak demand period.

The base-case lighting sources in this study are relatively modern and efficient. Additionally, the four existing fluorescent lamps were powered by only one 2-lamp ballast. This anomaly was discussed with the case manufacturer. While it is possible that the case was originally equipped with (2) ballasts, it is also possible that the configuration was a result of changes made in the field. Therefore, these savings estimates are likely conservative, relative to baseline equipment that may be present in other facilities.

6.1.3 Annual Energy Savings

As described in the previous section, the base case lighting systems operate during store hours. No operational changes were made to the evaluated lighting systems during the course of the study.

Replacement of the base-case lighting systems with test-case lighting resulted in a combined savings (lighting and refrigeration) of 705 kWh per year in energy savings.

Table 6-2 Project Energy Savings

System	Operating Hours [hr/yr]	Annual Energy Savings/Case [kWh/yr]	Annual Energy Savings/Door [kWh/yr]
Lighting System	6,022	470	156
Refrigeration System	6,022	235	73
	Total Annual Energy Savings [kWh/yr]	705	229

6.2 Maintenance Savings

6.2.1 Effective Useful Life

Manufacturers, including the manufacturers who provided the products for use in this study, tend to report an effective useful life (EUL) for LED lighting systems of at least 50,000 hours in product specifications. The manufacturer of the light bars used in this study sets end of life at 70% lumen maintenance, per recent standard LM-80, issued by the IESNA in October 2008; EUL is stated as 50,000 hours, however, no independent test data was available for corroboration. At the operating hours (6,022 hr/yr) in this study, EUL is calculated at 8.3 years, over twice the lifetime of the fluorescent lighting system.

Verification by formal testing is important since LED performance and lifetime is heavily affected by drive current, thermal management, and ambient temperature. The DOE has reported testing at the LRC which demonstrates the significant deficit in lifetime of an LED source caused by an 11 °C difference in operating temperature.[19] This information is now dated, especially considering the quickening development of LED technology, but demonstrates the need for conservative estimates of EUL given the current instability of the market, lack of independent laboratory product testing, and influence of thermal management and ambient temperature.

6.2.2 Lifecycle Impacts

Replacing fluorescent lighting systems with LED lighting systems will typically result in avoided maintenance costs over the life of the new LED system. Since the LED lighting systems have a longer EUL, they will incur fewer equipment replacements and lower maintenance costs over their life.

Maintenance savings are based on more than two cycles of avoided fluorescent lamp replacement during the lifetime of the LED lighting system. Maintenance savings also assume that a small percentage (10.0 percent) of ballasts for the fluorescent lighting

[19] (Building Technologies Program February 2007)

systems will fail annually; the percentage of actual failures will likely be higher or lower depending on the age of the ballasts.[20]

The avoided costs due to maintenance are calculated to average approximately $114.24/yr over the life cycle of the LED source. These savings are included in the project economics as shown in Table 6-3.

Table 6-3 Annual Energy and Maintenance Cost Savings

Annual Cost Savings				Simple Payback Period (yrs)	
Energy ($/yr)	Maint. ($/yr)	Total ($/yr)	Project Cost	Energy Savings Only	Energy and Maintenance Savings
$81.43	$114.24	$195.67	$879.48	10.8	4.3

[20] The overall avoided maintenance costs during the expected life of the LED system are calculated in Appendix C-2.

6.3 Photometric Performance

As discussed in Section 4.3, photometric field measurements were established for the fluorescent and LED lighting systems. Surface maps were generated from the measurement points to enable the visual comparison of both quantity and uniformity. Additionally, maximum, minimum, and average measurements as well as uniformity ratios are included for comparison.

6.3.1 Luminance

Figure 6-3 compares the luminous intensity of the baseline and LED luminaires. The plane of each chart represents the surface of the foam-core board, upon which were mapped the eighteen luminance measurements that occur at the intersection of the gridlines of each axis. The shift in uniformity is easily observed, as is the reduction in overall luminance levels.

Figure 6-3 Fluorescent (left) and LED (right) Luminance Surface Maps (cd/m^2)

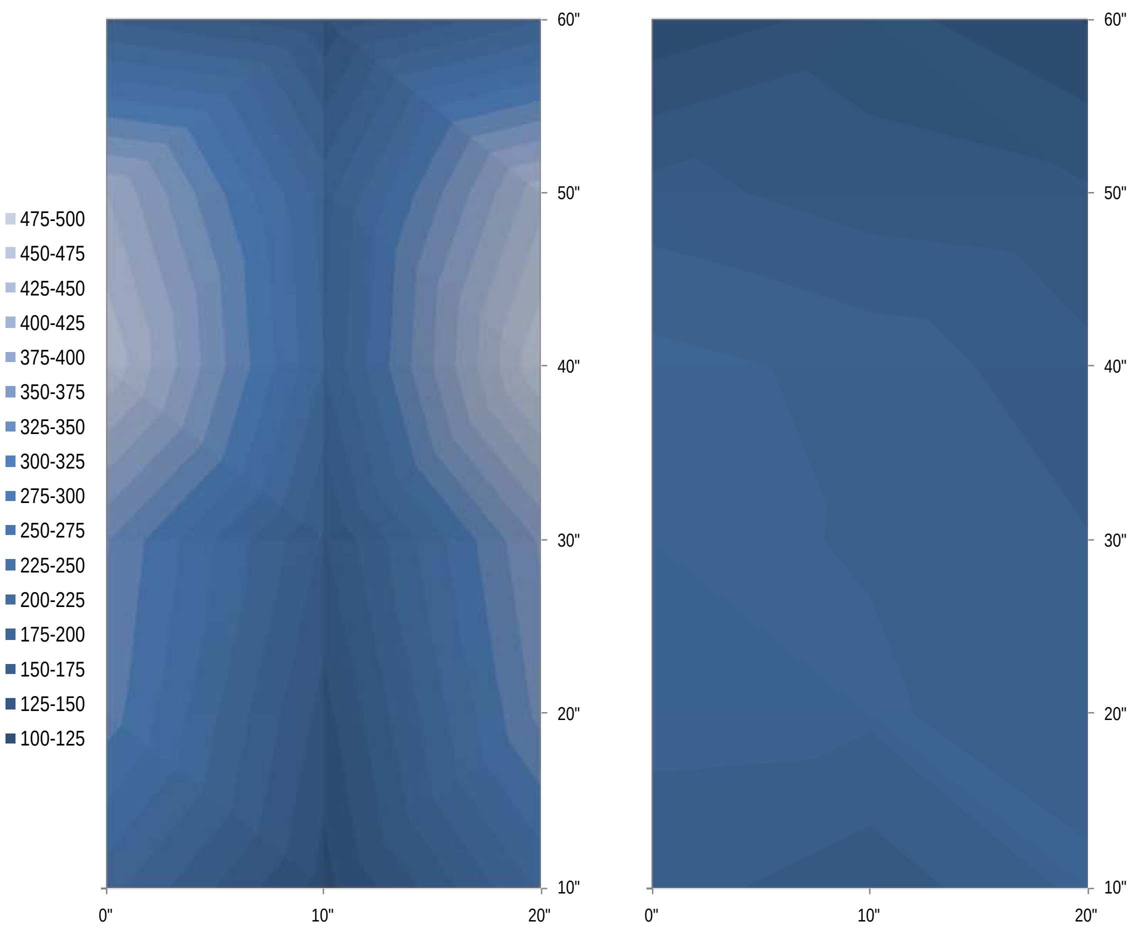


Figure 6-4 and Table 6-4 provides more detailed indicators of performance. While the maximum level of luminance was approximately halved, the uniformity ratios reveal that the mean level of luminance provided to the entire freezer case was reduced by a much lesser amount.

Figure 6-4 Minimum, Average, and Maximum Luminance Measurements (cd/m^2)

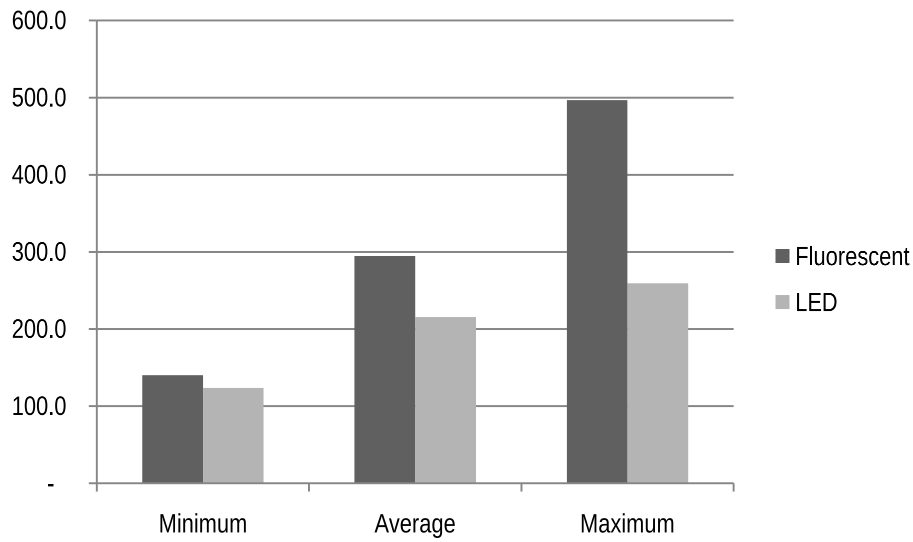


Table 6-4 Luminance Uniformity Ratios

	Baseline Fluorescent Lighting	Replacement LED Lighting
Maximum to minimum ratio	3.5:1	2.1:1
Average to minimum ratio	2.1:1	1.7:1

6.3.2 Illuminance

Figure 6-5 compares illuminance measurements from the baseline and LED lighting systems. Again, the shift in uniformity is most striking, while illuminance levels are generally decreased and measurement values increased towards the bottom of the case with both baseline and LED lighting systems.

Figure 6-5 Fluorescent (left) and LED (right) Illuminance Surface Maps (fc)

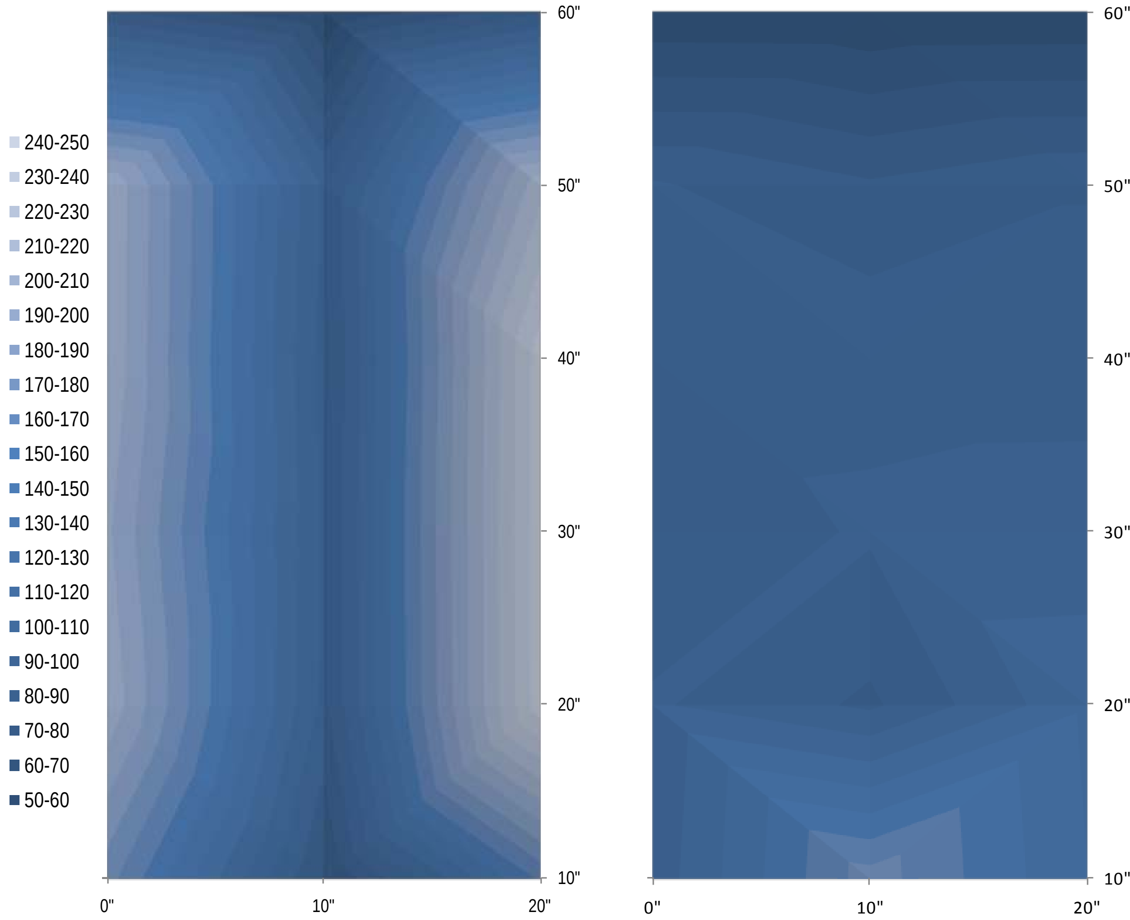


Figure 6-6 and Table 6-5 present more detailed information. Notably, minimum illuminance levels were increased. Uniformity was improved both in terms of maximum to minimum and average to minimum ratios.

Figure 6-6 Minimum, Average, and Maximum Illuminance Measurements (fc)

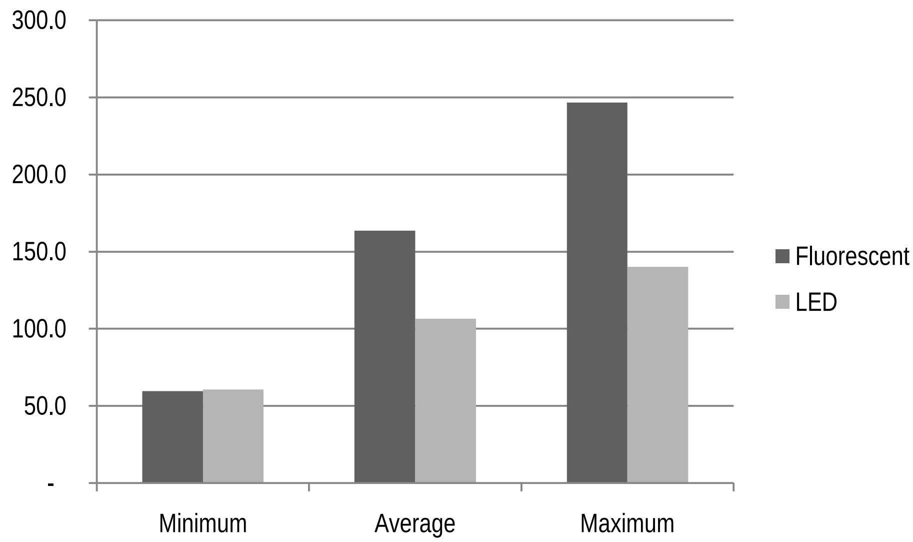


Table 6-5 Illuminance Uniformity Ratios

	Baseline Fluorescent Lighting	Replacement LED Lighting
Maximum to minimum ratio	4.1:1	2.3:1
Average to minimum ratio	2.7:1	1.8:1

6.3.3 Correlated Color Temperature

The CCT of the baseline fluorescent lamps was recorded at 3,645 K. The manufacturer rated the baseline fluorescent lamps at 4,100 K.

The CCT of the replacement LED products were measured at 5,032 K and was manufacturer-rated at 5,100 K.

6.4 Incremental Cost for Materials and Installation

Since this demonstration and assessment project replaced existing, functioning lighting systems with new LED lighting systems, the incremental cost of the project is the actual installed cost of the new lighting systems. The incremental cost basis for economic evaluation should be the actual installed cost; however, in this case, the material and installation labor was provided at no cost to the end user.

The manufacturer did not provide firm pricing for the equipment or labor involved in this project. Based on an informal cost estimate from a previous study (Application Assessment Study #0722), the price of a light bar was set at $39/ft and an additional 20 percent of the total materials cost was included to account for the driver. With materials estimated at $744.00 and labor at $135.48, the retrofit of a 5-door freezer display case at was determined to be $879.48.

The labor cost used in the economic analysis for light bar installation was based on the observed installation, noted to be 0.420 hours per unit. The labor cost for each project was calculated based on the total unit labor hours for the project multiplied by the burdened labor rate for an electrician performing work in the local area. See Table 6-3 for a summary of project economics.[21]

6.5 Customer Feedback

Feedback was solicited from employees at the host site. The survey asked respondents to rate their level of satisfaction with the replacement lighting system, with regards to the following factors, among others:

- Visual interest in the merchandise
- Amount of light
- Personal preference

Customer survey responses had not been received as of the completion of this report.

[21] Additional information is provided in Appendix C-2.

7 Discussion

7.1 Site Coordination and Product Installation

The demonstration project was well coordinated between the host customer, the utility, and the project evaluation team and no significant issues or observations were noted.

While no problems were observed with installation of the LED light bars, irregular configuration was noted of the baseline fluorescent lighting system. Only one 2-lamp ballast was verified to have been installed in the case; power measurements support this observation. According to the freezer case manufacturer, four lamps should have been powered by two 2-lamp ballasts; it is possible that this configuration was a result of changes made in the field. Nonetheless, the irregular configuration of the baseline lighting system bears relevance to demand savings calculations presented in Section 6.1.2 and discussed below.

7.2 Product Evaluation

7.2.1 Comparison of Baseline and LED Lighting System Performance

The project resulted in considerable energy savings, 117 W for the entire freezer case, or 39 W per door, and a limited reduction in light output, both in terms of luminance and illuminance. Uniformity ratios were generally improved with the LED lighting system.

Table 7-1 Comparison of Baseline and LED Lighting System Performance (Luminance/Illuminance)

	Average [22]	Maximum to Minimum Ratio	Average to Minimum Ratio
Luminance [cd/m^2]			
Fluorescent	294.6	3.5:1	2.1:1
LED	215.3	2.1:1	1.7:1
Δ (%)	26.9%	-	-
Illuminance [fc]			
Fluorescent	163.7	4.1:1	2.3:1
LED	106.6	2.7:1	1.8:1
Δ (%)	34.9%	-	-

Table 7-2 Comparison of Baseline and LED Lighting System Performance (Electric Demand)

	Lighting System [kW]	Refrigeration System [kW]	Total [kW]
Refrigerated Case			
Fluorescent	0.186	0.094	0.280
LED	0.108	0.055	0.163
Δ (%)	41.9%	41.5%	41.8%
Door			
Fluorescent	0.062	0.031	0.093
LED	0.036	0.019	0.055
Δ (%)	41.9%	38.7%	40.9%

[22] Although the reduction in level of light agrees with the general trend of application assessment studies of LED lighting, a basic evaluation of the distribution of the dataset from each lighting system bears relevance to a thorough comparison. Importantly, the standard distribution of luminance and illuminance measurements for the fluorescent lighting was twice that of the standard distribution for measurements the LED lighting system.

	Luminance (μ/σ)	Illuminance (μ/σ)
Fluorescent	294.6/115.6	163.7/63.9
LED	215.3/43.6	106.6/25.2

Since the distribution of the of the fluorescent lighting is especially characterized by the intensity of light provided to the peripheries of the freezer case (as shown in Figure 6-3 and Figure 6-4), it should be noted that the overall level of lighting in the baseline lighting system was at greater variance to the reported mean as compared to the LED lighting, which may underemphasize the ability of LED light to match baseline light levels.

The measured product performance generally agrees with other application assessment studies, a summary of which is presented in Table 7-3.

Table 7-3 Summary of Product Performance by Application Assessment Study

Application Assessment # /Year	Lighting System	Lighting System Efficacy [lm/W][23, 24]	Average Electric Demand (Lighting) [W/door]	Average Measured Illuminance [fc] (Max. to Min. Ratio)
#0608/06-07	5' 58W HO T8 fluorescent	83.1	75	186 (3.0:1)
	LED Power Piranha	26.7	43	129 (5.6:1)
	Δ (%)	-	43%	31%
#0722/07-08	5' 40W T8 fluorescent	84.4	59	78 (1.2:1)
	LED Power Green Power	49.2 *(30.6)*[25]	28	45 (1.9:1)
	Δ (%)	-	53%	42%
#0723/08-09	5' 58W HO T8 fluorescent	-	62	164 (4.1:1)
	Philips Affinium LFM 200	-	36	107 (2.7:1)
	Δ (%)	-	42%	35%

7.2.2 Manufacturer's Claims and Product Performance

Since LED lighting technology is still emerging and evolving, much inconsistency has been observed in the industry. Even as of 2008, testing results are at variance with manufacturer's claims:

> *"CALiPER testing continues to reveal that many SSL [solid-state lighting] products do not meet manufacturer performance claims, although a few high-performing products are emerging on the market and definite progress can be seen in some product categories."* [26]

Round 4 of CALiPER testing, in January of 2008, revealed that, for about 9 out of 15 SSL products tested, "information published by manufacturers regarding product output and/or efficacy overstated performance (by factors ranging from 30–600%)." [27]

Since independent laboratory testing of the products used in this assessment was not available (see Section 7.2.3) comparison between product specifications and project results are difficult to draw. Variance is considerable in the case of the LED light bars, especially when considering the supposed reduced power draw of the side modules. The discrepancy between the rated and measured demand of the fluorescent lamps is due to the configuration of four lamps to one 2-lamp ballast, as noted above.

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[23] Efficacy ratings based on measure electric demand and manufacturer specifications of lumen output.

[24] Efficacy rating for Phillips Affinium modules unavailable at time of report issuance.

[25] Efficacy rating from independent laboratory testing data.

[26] CALiPER Round 6

[27] (DOE Solid-State Lighting CALiPER Program January 2008)

Table 7-4 Demand Performance

Lighting System	Reported Electric Demand (W)	Average Measured Electric Demand (W)
Fluorescent	58	47
LED	15-25	27

7.2.3 Independent Product Laboratory Testing

The manufacturers were unable to provide independent laboratory test data for the products tested in this study at the time of the issuance of this report.

Independent testing usually includes the measure of total luminous flux, input electrical power, luminaire efficacy, luminous intensity distribution, lumen maintenance, correlated color temperature, and other standardized performance characteristics.

Independently verified distribution data would have been particularly useful in interpreting field measurements and end user perceptions. Since LED lighting system performance is often amplified by the accurate delivery of light from source to application, this information is especially useful. Independent laboratory efficacy ratings would also have been integral to a thorough evaluation of luminaire efficacy as a comparison with manufacturer's claims. It is recommended for future studies of this type that lighting samples be provided to independent agencies for laboratory testing during the initial phases of implementation. IESNA LM-79-08 details electrical and photometric testing methodology specifically addressed to the unique requirements of solid-state lighting.[28] This standard is quickly being adopted by the industry, and, along with IESNA-80-08 and ANSI C78.377-2008, which address lumen depreciation and chromaticity, respectively, will become more and more necessary for the evaluation of LED lighting systems.

7.2.4 Luminaire Performance

Efficacy is the standard definition for lighting performance, defined as "the ratio of light from a lamp to the electrical power consumed, including ballast losses, expressed as lumens per watt."[29]

This study approaches lighting performance differently, since only field measurements of photometric and electric demand data were available. Illuminance ratings were adopted as the primary indicator of luminaire performance, as this rating reflects the incident light important to customer and retailer perception. While not as controlled as laboratory measurements, illuminance measurements also offer insight into luminaire optics and other environmental factors.

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[28] (IESNA February 2008)

[29] (Nebraska Government n.d.)

The LED luminaires demonstrated considerable reduction in energy consumption, 41.9 percent, while only reducing illuminance levels by 29.6 percent. When coupled with refrigeration savings, this application of LED lighting is proven to be efficient. Moreover, the uniformity of light delivered to the task may mitigate the actual drop in illuminance levels from the end-user's perspective.[30] Therefore, the overall ability of the LED light bars to serve as efficacious sources in this application is further enhanced.

7.3 Measure Feasibility and Market Potential

7.3.1 Current Feasibility and Potential

This measure is technically feasible but is not cost-effective with current market conditions. The projected simple payback period is 10.8 years based on energy savings alone, 4.3 years when maintenance savings are included. Only when maintenance savings are included does the payback period fall within the system EUL of 8.3 years.[31]

The reduction of energy use in the retail sector can be a challenging task because services are driven by a need for customer satisfaction, in turn dependent on their visual and physical comfort. Nonetheless, the DOE Efficiency and Renewable Energy Building Technologies Program states that "Lighting is the biggest energy expense for retailers—37 percent of total energy use."[32] This demonstration project achieves reduction in lighting energy usage, while maintaining customer acceptance. The adoption of this technology in the retail industry depends mainly on the development of LED materials science and the contribution of developing LED product and installation markets in reducing costs to the grocery store.

7.3.2 Cost and Performance Projections

Widespread adoption of solid-state lighting rests both on suitability of application and cost effectiveness. Suitability issues are largely performance issues, including color, distribution, product life, and power requirement, and are discussed elsewhere in this report.

Cost effectiveness criteria vary, but life-cycle cost analysis, for example, generally consider first costs, operating costs, useful life, cost of disposal, and economic factors such as depreciation and escalation. The industry generally measures lighting cost effectiveness in terms of the first cost associated with a given level of lumen output, as reported in dollars per kilolumen ($/klm). In reporting and projecting future trends in cost effectiveness, this metric accounts for change in production cost and source efficacy; that is to say, dollars or kilolumens, respectively. The potential of LED technology for rapid change in these terms is expressed in general terms by Haitz's Law, which predicts that every 10 years, efficacy will increase by a factor of 20, while cost will decrease by a factor of 10.

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[30] Raghavan, Ramesh and Narendran, Nadarajah, 2002

[31] These estimates are based on an effective useful life of 50,000 hours and associated maintenance savings. See Appendix C for cost-effectiveness calculations.

[32] DOE Efficiency and Renewable Energy Building Technologies Program. <http://www1.eere.energy.gov/ /buildings/commercial/retail.html>

The DOE projects the market penetration for white LED lighting applications based on technological development and materials and manufacturing cost improvements.[33] The modeling system is based on the state of the industry in 2001, at which time market penetration was defined as zero, and the cost of medium CRI LED technology was set at $275/klm.[34, 35] The most conservative projection for 2010 predicted efficacy would reach 45 lm/W and cost would reduce to $36/klm; the report's most conservative scenario predicted a cost of approximately $8/klm by 2020, while the least conservative model predicted a cost of approximately $0.50/klm.[36]

A comparison of the predictive models can be drawn against the current state of the industry as a partial validation of the models. LED efficacy testing in accordance with LM-79 protocol has already exceeded the predicted efficacy of 45 lm/W in numerous applications including a 2007 DOE typical performance value of 54 lm/W for medium CRI LED technology.[37]

The same multi-year program plan for solid-state lighting research and development, issued by the DOE in 2008, offers updated pricing prediction models. These models demonstrate that the 2001 study's projected performance has already been exceeded; the pricing for a 1 W cool-white LED source was reported to be $35/klm in 2006 and $25/klm in 2007: cost reductions beyond Little's prediction of $36/klm in 2010.[38, 39] This more recent DOE model further predicts LED source technology to reach price points of $10/klm in 2010, $5/klm in 2012, and $2/klm in 2015. It should be noted, however, that the full price of an LED luminaire (~$100/klm in 2008) is greater than that of the device.[40]

7.4 Future Technology Improvements

7.4.1 Increasing Industry Standardization

The development of LED lighting standards is continuing at a rapid pace; 2008 saw the release of:

- ANSI C78-377-2008. *Specifications for the Chromaticity of Solid-State Lighting Products for Electric Lamps*. February 2008.
- IESNA LM-79. *Approved Method: Electrical and Photometric Testing of Solid-State Lighting Products*. May 2008.

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33 (Little 2001)

34 *Ibid.*

35 CRI becomes a determining factor in cost effectiveness due to the expense of the phosphor coating needed to achieve a given CRI level.

36 *Ibid*.

37 (Navigant Consulting, Inc. March 2008)

38 *Ibid*.

39 *Ibid.*

40 *Ibid.*

- IESNA LM-80. *Approved Method for Measuring Lumen Depreciation of LED Light Sources*. October 2008.

Furthermore, ENERGY STAR criteria for solid-state lighting luminaries, which went into effect on September 30, 2008, stipulate minimum linear flux levels. Importantly, this represents the increasing acceptance of the directionality and focus of LED lighting, which bears relevance to this application study.

Major standards in development include IESNA RP-16 (Definitions), ANSI C82-.XX1 (Power Supply), and UL 8750 LED (Safety). These standards will help coalesce the industry's offerings in terms of quality and performance, which should in turn bring a greater reliability of performance in the marketplace.

7.4.2 Projected Improvements in Manufacturing and Materials Science

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. Manufacturers are working to improve thermal efficiency to enhance expected life and light output.

The combination of advancements in materials science, luminaire design, technology adoption, and market stabilization is expected to result in continued improvement in the viability and cost-effectiveness of LED lighting technology.

8 Conclusions

The reduction of energy use in the retail sector can be a challenging task because services are driven by a need for customer satisfaction, in turn dependent on their visual and physical comfort. Customer survey results were not available at the time of issuance of this report so as to enable an evaluation of end-user acceptance.

The other major traditional barrier to implementation is cost-effectiveness. The data support a significant savings opportunity for this type of application. However, the cost of implementation at current market conditions is only attainable within the entire EUL of the system. It is also 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 system configuration, lighting wattage, system operating hours, refrigeration system characteristics, climate zone, and utility rate structure.

PG&E uses this and other Emerging Technologies assessments to support the development of potential incentives for emerging energy efficient solutions. While, the cost-effectiveness barrier to the wide-spread adoption of LED technology is expected to be overcome with maturing market conditions, the potential energy savings of LED technology in this end-use are significant. As increasing standardization and stabilization of the industry are rapidly progressing, incentive programs to accelerate cost-effectiveness seem viable and warranted.

Nonetheless, 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.

Finally, this study does not reveal findings which significantly advance current understanding of the photometric performance of LED light bars. However, the methodology employed in this study in measuring photometric performance, as conceptualized by the DOE, underscores the increasing awareness of the accuracy and uniformity required when evaluating, designing, or otherwise characterizing LED lighting systems.

9 Recommendations for Future Work

Independent research is needed to further develop the performance, potential application, and adoption of LED lighting sources. Recent implementation of standards for LED chromaticity, electrical testing, photometry, and lumen depreciation have provided the industry with a set of laboratory test protocols and metrics. The development of these standards marks the beginning of a maturing solid-sate lighting technology by leveling performance metrics in the laboratory.

Nonetheless, this study outlines areas in two general categories which would help to accelerate the adoption of LED light sources.

9.1 Field Performance

The cornerstone of customer acceptance and technology adoption is field performance; evaluation of field performance is the domain of the application assessment study. Three substantial, broad areas of performance are suggested by customer concerns and by the availability of emerging standards.

1) *Lumen depreciation in cold temperature environments.*
   The implications of lumen depreciation in LED sources to lifecycle cost analysis and customer adoption have been raised as an impact worthy of further study in past assessment studies. While life is currently assessed by laboratory testing, laboratory conditions do not mimic the range of operating temperatures found in the freezer case environment. An extended in-field study would be a useful tool in assessing the actual long-term performance of LED light sources in freezer environments, especially in respect to manufacturer's claims. A thorough study would require several years, but would yield actual results on the implications of alterations to drive current and thermal management to lumen depreciation. These implications relate to life cycle cost and, therefore, to customer acceptance.

2) *Standardization of in-field testing methodology and performance metrics.*
   The inherent difference in the quality of light provided by LED lighting calls for a carefully formed evaluation of performance. While standardization in laboratory testing continues to be adopted, similar improvements in the testing methodologies of field testing would better characterize solid-state lighting system performance. Recent ASSIST standards are one such example of the recommended research.[41]

[41] "Recommendations for Testing and Evaluating Luminaires for Refrigerated and Freezer Display Cases." ASSIST. Lighting Research Center at the Rensselaer Polytechnic Institute. Volume 5, Issue 1, November 2008.

3) *Refrigerated case system design.*
   Detailed photometric analysis of the effect of the nano-optical design of LED luminaires would offer insight into the optimal fixture design, placement, and orientation for meeting the requirements of highlighting merchandise in the freezer case environment. Since there is much variation in the current market in regards to form factor and optical design, and solid-state lighting technology differs so inherently from conventional lighting, such a study would offer an initial outline of design guidelines for these emerging systems. Results would benefit application assessment and other in-field studies, while offering preliminary design guidance to early adopters.

9.2 Market Assessment

Equally important to market acceptance and adoption is the perception of value. The LED technology has gained a foothold in the marketplace, which suggests two related areas in market research as recommended for further evaluation:

1) *Market growth and trend*s.
   The LED lighting market has matured to the point where major equipment vendors, including Anthony Doors and Hussmann, offer LED lighting systems alongside conventional fluorescent systems for illuminating freezer case doors. Research of manufacturer sales data would reveal trends in configuration and sales volume related to LED lighting systems, and would aid in soliciting further customer acceptance feedback.

2) *End-use customer survey.*
   Widespread surveys of early technology adopters and customers would provide valuable information on the potential for equipment adoption. Specifically, due to the directionality and uniformity of LED lighting, it is often posited that these factors allow an overall reduction in light level while maintaining user satisfaction. Systematized surveys and analysis of the resulting data may allow the establishment of an updated set of acceptance thresholds for solid-state lighting technology.

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Appendices

EMCOR
Energy Services

Appendix A

Test Protocol

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

Testing Protocol for LED Lighting in Refrigerated Case Applications (Freezer)

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

The LED strip lighting will be tested in a three-door freezer case located in the San Miguel Marketplace in Stockton, California.

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. Instrumentation Specifications

1. Konica Minolta LS 100 Luminance Meter
    a. Measures surface and light source luminance.
    b. Sensor focuses to a 1° acceptance angle with a 9° field of view.
    c. Sensor: Range (Accuracy)
        i. Luminance: 0.001 to 299,900 candela/sq. meter (± 2% ± 2 digits)
        ii. Spectral Response: 400 to 760 nm

2. Konica Minolta CL 200 Chroma Meter
    a. Measures correlated color temperature and illuminance.
    b. Meter self-calibrates before use, and the hold button can be used to freeze the displayed illuminance value.
    c. Sensor: Range (Accuracy)
        i. Illuminance: 0.001 to 29,990 footcandles (± 2% + 1 digit of displayed value)
        ii. Wavelength: 400 nm to 760 nm

3. DENT Instruments ElitePro Logger
    a. Measures power, current, voltage and power factor.
    b. Poly-phase recording power meter with four integrated voltage references.
    c. Sensor: Range (Accuracy)
        i. Current: 0 to 6,000 Amps (0.5% typical, meter only)
        ii. Volts: 0 to 600V AC or DC
        iii. Frequency: 50 or 60 Hz
    d. Resolution: 12-bit
    e. Memory Records: 25,000 records

V. Setup Protocol

1. Existing fluorescent lamps must be replaced with new fluorescent lamps and the new lamps must be "burned in" for at least 100 hours to stabilize the baseline condition. The purpose for the adjustment to the baseline condition is to ensure that the light output of both existing and replacement light sources is compared at the same point of depreciation, in this case as "new". Failed ballasts in test areas should likewise be replaced.

2. Prior to taking lighting measurements, 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.

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. EES will record the manufacturer and model information of the doors as available on site.

VI. 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. Place a white foam core board between the freezer door and the merchandise to facilitate consistency in the luminance environment.
    b. Measure luminance values on the test grid with the freezer door closed using a Konica Minolta LS100 Luminance Meter.
    c. Record the distance at which the measurements were taken.
    d. 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 (CCT)
    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 their lab for testing.

   b. EES will coordinate with the CLTC to obtain test results and incorporate results into the report.

5. Determine Power Usage and System Run-Time
   a. Work with the host site electrician to identify the circuit powering the test case.
   b. Oversee installation of a Dent Elite-Pro data logger by host site 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 cooling the test case and note additional loads served by the compressor, if any.
   b. Record all pertinent nameplate data available for the compressor.
   c. Record the temperatures inside the refrigerated cases.

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.

VII. Evaluation

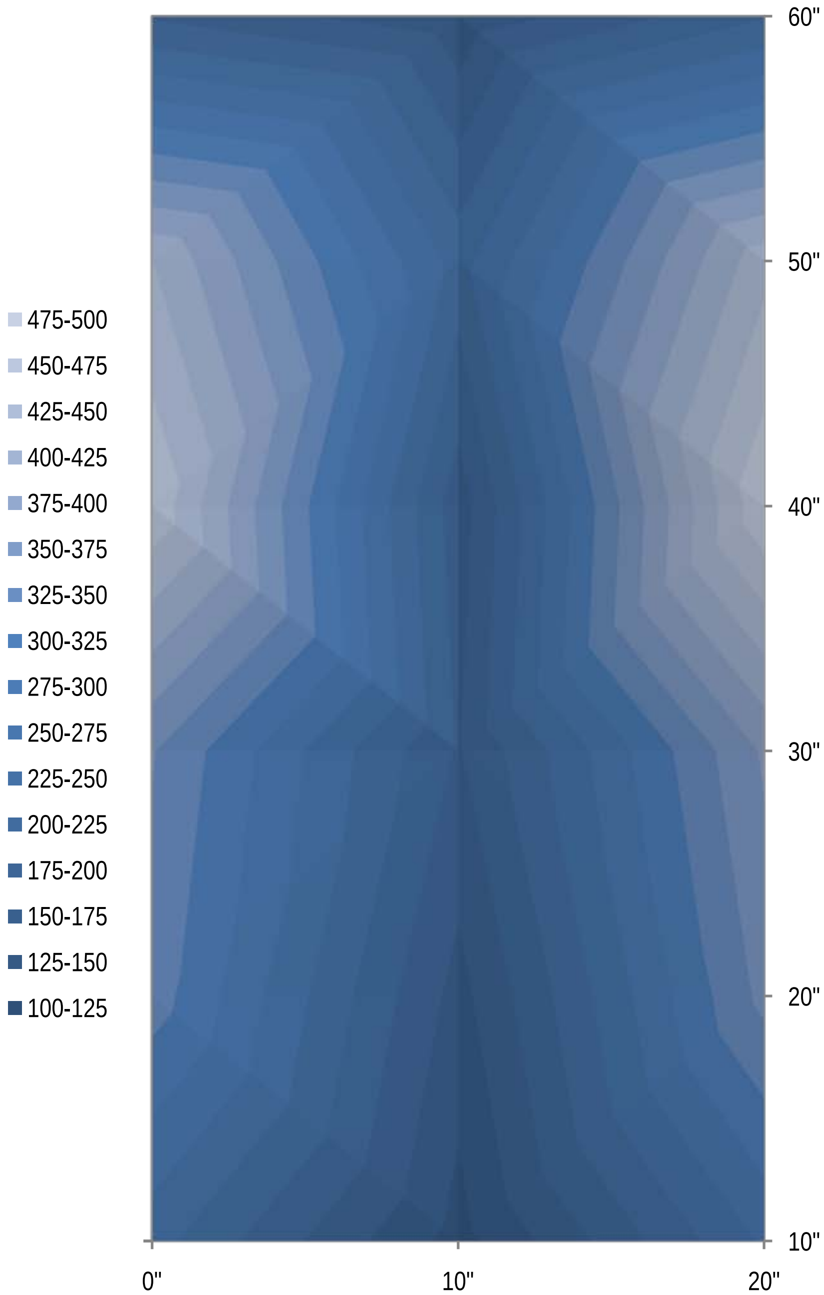
Upon completion of testing, collected data will be evaluated to determine the energy savings and lighting performance of the emerging technology.

EMCOR Energy Services

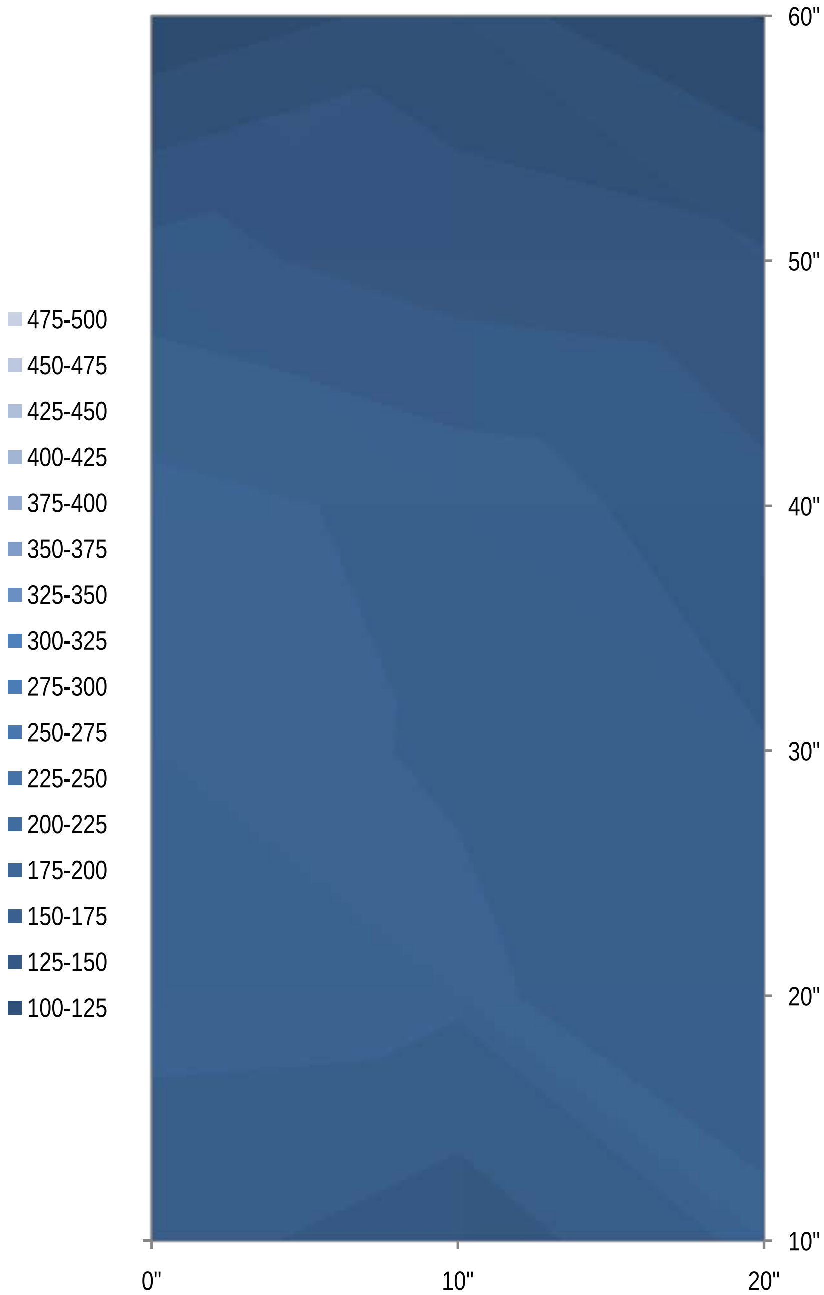
Appendix B

Luminance and Illuminance Surface Maps

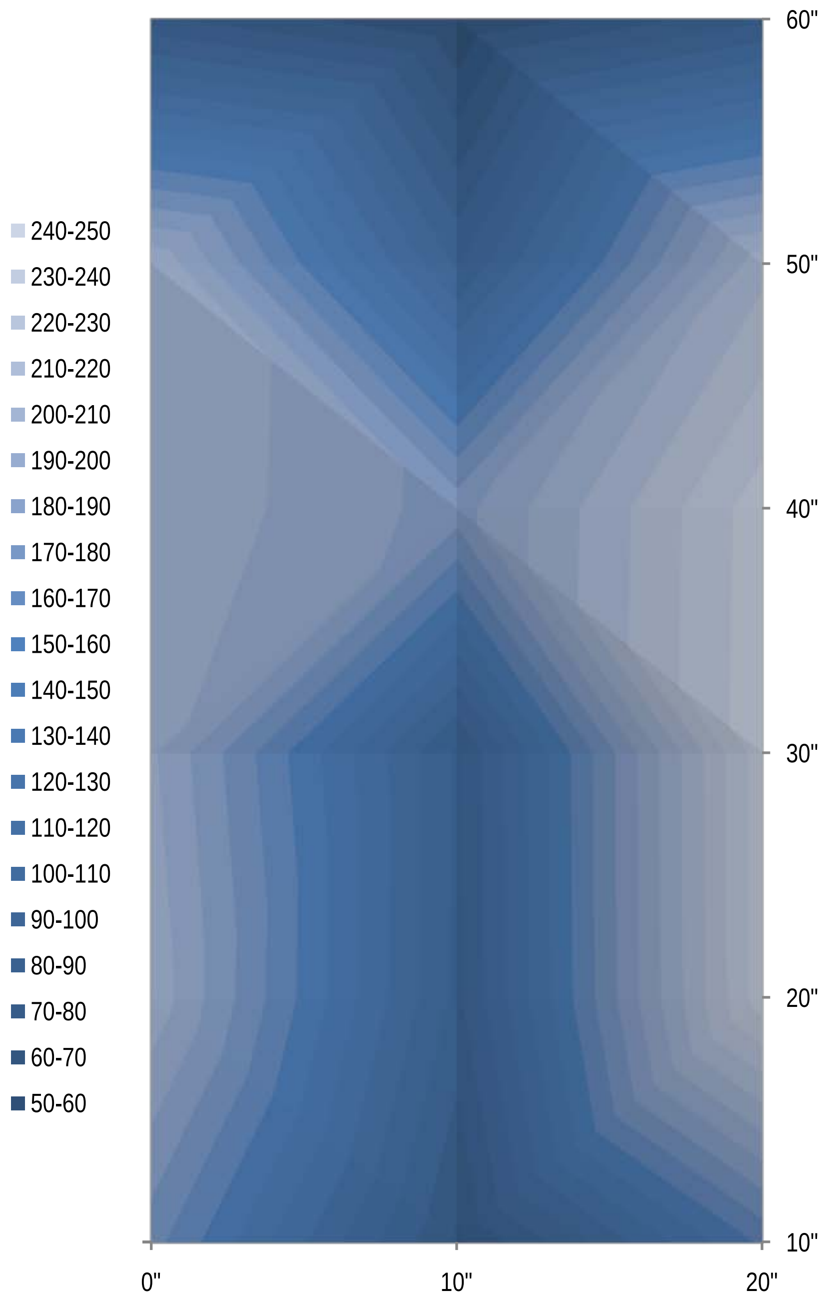
Fluorescent Luminance Map



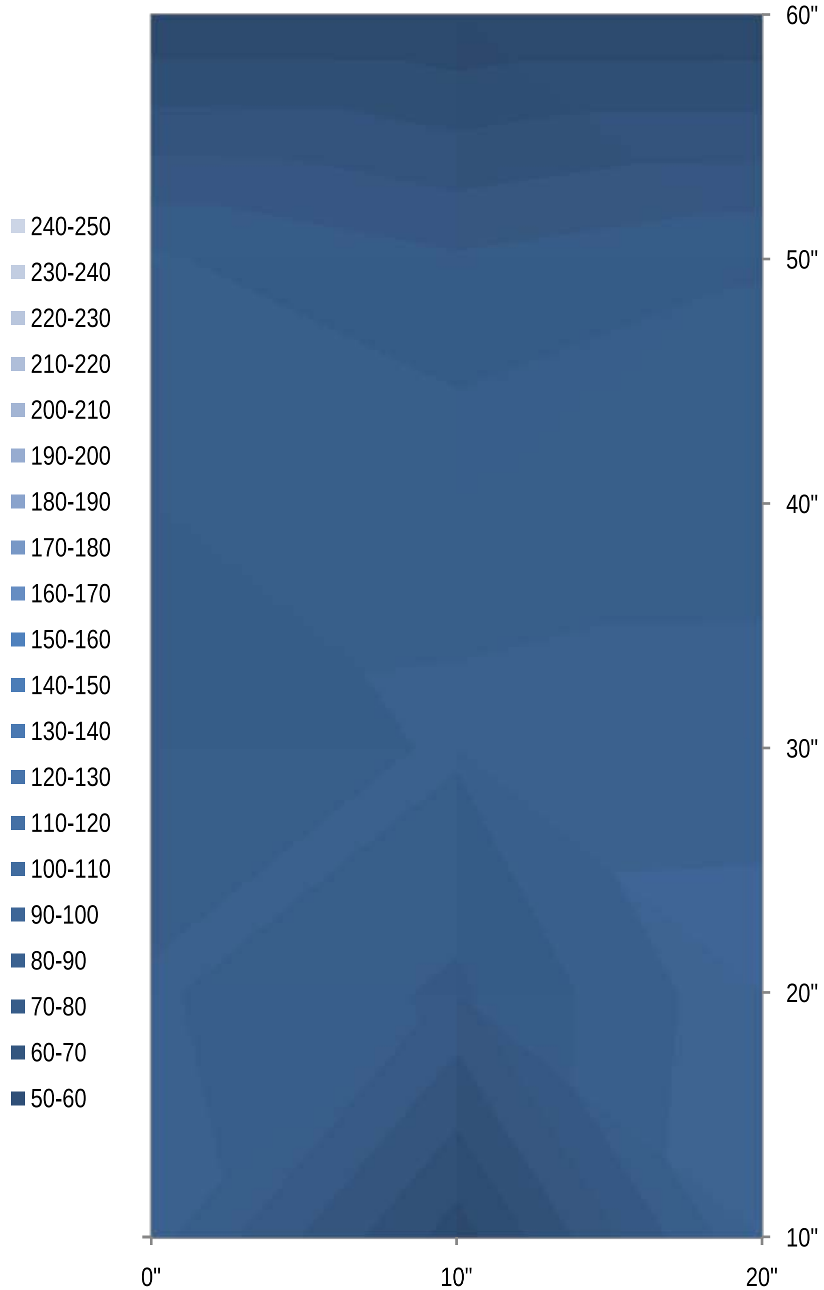
LED Luminance Map



Fluorescent Illuminance Map



LED Illuminance Map



Appendix C

Calculations

EMCOR Energy Services

Appendix C-1

System Efficacy

PG&E Emerging Technology Study: Refrigerated Case Lighting
San Miguel Market (Stockton) Energy Savings

Energy Savings (Lighting)

This project replaced (4) 5' T8 fluorescent lamps and associated ballasts with (4) 5' LED light bars in a 3-door Hussmann Low Temp Reach-In Freezer Case. The "Measured Electric Demand" was determined from (1) metered circuit which consisted of the lighting for the test freezer only. "Annual Operating Hours" for this circuit are 6,022 hours/year (16.5 hours/day * 365 days/year). This operating schedule is supported by the data collected from the measured circuit.

Lighting System	Measured Electric Demand [kW]	Annual Operating Hours [hr/yr]	Energy [kWh/yr]
Refrigerated Case			
Fluorescent	0.186	6,022	1,120
LED	0.108	6,022	650
Δ	**0.078**		**470**
Δ [%]	**41.9%**		**42.0%**
Door			
Fluorescent	0.062	6,022	373
LED	0.036	6,022	217
Δ	**0.026**		**156**
Δ [%]	**41.9%**		**41.8%**

Luminaire	Luminaire Quantity	Demand/ Luminaire [kW]
Fluorescent	4	0.047
LED	4	0.027
Δ		**0.020**
Δ [%]		**42.6%**

Energy Savings (Refrigeration) (1)

LED light bars and associated drivers produce less heat than fluorescent lamps and associated ballasts, resulting in refregeration energy savings. The "Thermal Energy / Door" was determined using Hussmann's Technical Data Sheet for th 3-door Model RL Freezer Case. Additionally Hussmann states on their Technical Data Sheet that "Optional LED lighting reduces refrigeration load by 100 Btu/hr/Door". Thermal Energy (Btu/hr) is converted to Electric Demand (kW) using 1 Btu/hr = .293 Watts. The "Annual Operating Hours" will be the same as above because savings are realized only during the hours which the lights are operating.

Lighting System	Measured Electric Demand [kW]	(2) Ballast Power Draw [%]	Lamp Power Draw [%]	(3) Power to Heat [%]	(4) Heat Load Source [kW]	(5) Compressor Load [kW]	Annual Operating Hours [hr/yr]	Energy [kWh/yr]
Refrigerated Case								
Fluorescent	0.186	10%	90%	79%	0.132	0.094	6,022	566
LED	0.108	10%	90%	79%	0.077	0.055	6,022	331
Δ					**0.055**	**0.039**		**235**
Δ [%]						**41.5%**		**41.5%**
Door								
Fluorescent	0.062	10%	90%	79%	0.044	0.031	6,022	187
LED	0.036	10%	90%	79%	0.026	0.019	6,022	114
Δ					**0.018**	**0.012**		**73**
Δ [%]						**38.7%**		**39.0%**

Savings Summary

	Case	Door	
Electric Demand Savings [kW]	0.117	0.038	
Energy Savings [kWh]	705	229	
Energy Rate [$/kWh]	$ 0.1155	$ 0.1155	*per Project Rate Calculation (Schedule E-19S)*
Annual Dollar Savings, Energy [$]	$ 81.43	$ 26.45	
Annual Avoided Maint. Cost [$]	$ 114.24	$ 38.08	*per Avoided Maintenance Cost Calculation*
Total Annual Savings [$]	$ 195.67	$ 65.22	

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

(2) Power distribution between lamp and ballast based on conservative assumption.

(3) Power to heat ratio based on IESNA Handbook, 9th Edition, p. 6-29. Also per "energy-Efficient Lighting Alternative for Commercial Refrigeration", Narendran/Brons/Taylor, RPI Lighting Research Center, November 16, 2006.

(4) Total measured laod to heat, eliminating ballast/driver energy and visible light.

(5) Based on refrigeration coefficient of performance (COP) of 1.4 calculated from energy efficiency ratio (EER) (COP=EER/3.412), assumes an EER of 4.9. 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=DBadj+15; for low temperature (LT): SCT=DBadj+10.

Where Dbadj is the dry-bulb temperature (F) of ambient or adjacent space where the compressor/condensing units reside. Defaults are based on climate zone design values, where Dbadj = 100 for the Central Valley - Sacramento climate (Zone 12).

PG&E Emerging Technology Study: Refrigerated Case Lighting
San Miguel Market (Stockton) **Luminance Analysis**

Luminance Measurements (cd/m²)

Fluorescent	0"	10"	20"
60"	195.9	155.6	222.2
50"	425.7	239.9	441.2
40"	470.9	186.0	496.6
30"	352.0	197.4	378.9
20"	338.1	165.9	357.5
10"	260.0	140.0	279.3

LED	0"	10"	20"
60"	130.9	160.5	123.6
50"	210.1	186.9	178.3
40"	259.1	242.5	206.6
30"	258.3	247.8	226.4
20"	256.7	254.7	231.2
10"	236.7	208.6	257.1

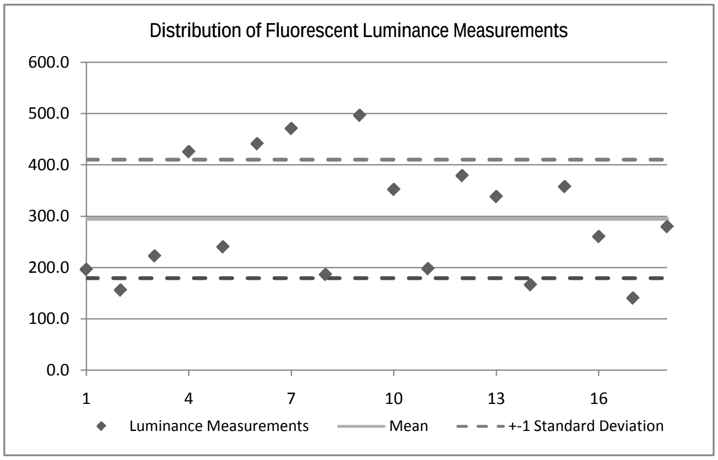
	Fluorescent		LED	
Minimum (cd/m²)	140.0		123.6	
Average (cd/m²)	294.6		215.3	
Maximum (cd/m²)	496.6		259.1	
Max:Min	3.5	:1	2.1	:1
Avg:Min	2.1	:1	1.7	:1

Analysis of Data

Fluorescent

Measurement Point	Measurement (cd/m²)	#σ
1	195.9	1
2	155.6	1
3	222.2	1
4	425.7	-1
5	239.9	0
6	441.2	-1
7	470.9	-2
8	186.0	1
9	496.6	-2
10	352.0	0
11	197.4	1
12	378.9	-1
13	338.1	0
14	165.9	1
15	357.5	-1
16	260.0	0
17	140.0	1
18	279.3	0

Distribution	
3	0.0%
2	0.0%
1	38.9%
0	27.8%
-1	22.2%
-2	11.1%
-3	0.0%

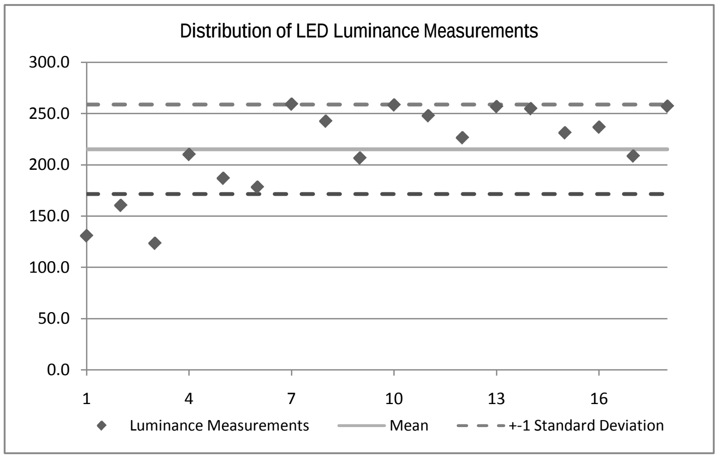


Mean (cd/m²) 294.6
Standard Deviation (cd/m²) 115.6

LED

Measurement Point	Measurement (cd/m²)	#σ
1	130.9	1
2	160.5	1
3	123.6	1
4	210.1	1
5	186.9	1
6	178.3	1
7	259.1	0
8	242.5	0
9	206.6	1
10	258.3	0
11	247.8	0
12	226.4	1
13	256.7	0
14	254.7	0
15	231.2	1
16	236.7	1
17	208.6	1
18	257.1	0

Distribution	
3	0.0%
2	0.0%
1	61.1%
0	38.9%
-1	0.0%
-2	0.0%
-3	0.0%



Mean (cd/m²) 215.3
Standard Deviation (cd/m²) 43.6

PG&E Emerging Technology Study: Refrigerated Case Lighting
San Miguel Market (Stockton) **Illuminance Analysis**

Illuminance Measurements (fc)

Fluorescent	0"	10"	20"
60"	81.9	59.6	88.2
50"	209.1	108.7	216.7
40"	208.5	186.0	245.7
30"	201.9	108.4	246.6
20"	207.6	107.5	246.0
10"	173.9	88.4	161.8

LED	0"	10"	20"
60"	61.2	60.6	61.0
50"	111.1	101.4	109.0
40"	117.1	117.7	117.8
30"	112.1	121.3	122.4
20"	121.3	108.1	138.3
10"	123.7	75.2	140.2

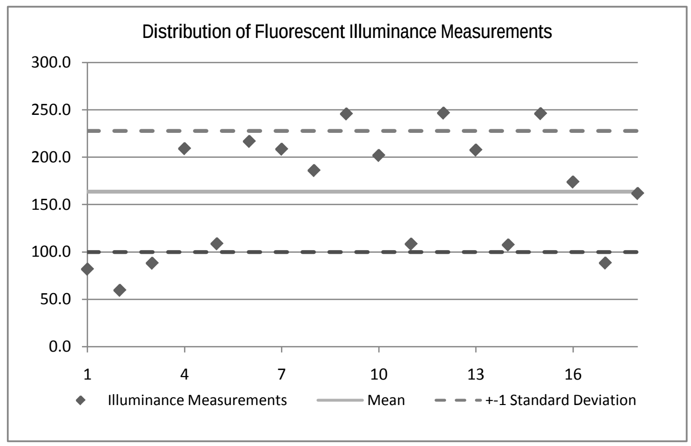
	Fluorescent		LED	
Minimum (fc)	59.6		60.6	
Average (fc)	163.7		106.6	
Maximum (fc)	246.6		140.2	
Max:Min	4.1	:1	2.3	:1
Avg:Min	2.7	:1	1.8	:1

Analysis of Data

Fluorescent

Measurement Point	Measurement (fc)	#σ
1	81.9	1
2	59.6	2
3	88.2	1
4	209.1	-1
5	108.7	1
6	216.7	-1
7	208.5	-1
8	186.0	0
9	245.7	-1
10	201.9	-1
11	108.4	1
12	246.6	-1
13	207.6	-1
14	107.5	1
15	246.0	-1
16	173.9	0
17	88.4	1
18	161.8	0

Distribution	
3	0.0%
2	5.6%
1	33.3%
0	16.7%
-1	44.4%
-2	0.0%
-3	0.0%

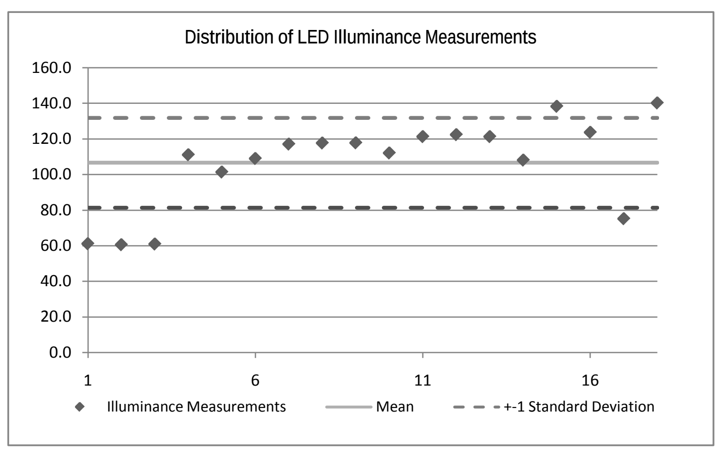


Mean (fc) 163.7
Standard Deviation (fc) 63.9

LED

Measurement Point	Measurement (fc)	#σ
1	61.2	2
2	60.6	2
3	61.0	2
4	111.1	1
5	101.4	1
6	109.0	1
7	117.1	1
8	117.7	1
9	117.8	1
10	112.1	1
11	121.3	1
12	122.4	1
13	121.3	1
14	108.1	1
15	138.3	0
16	123.7	1
17	75.2	1
18	140.2	0

Distribution	
3	0.0%
2	16.7%
1	72.2%
0	11.1%
-1	0.0%
-2	0.0%
-3	0.0%



Mean (fc) 106.6
Standard Deviation (fc) 25.2

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)

SCT	Low Temp EER (1)	Medium Temp EER (2)
70	8.5	186
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

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

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

Assumptions:

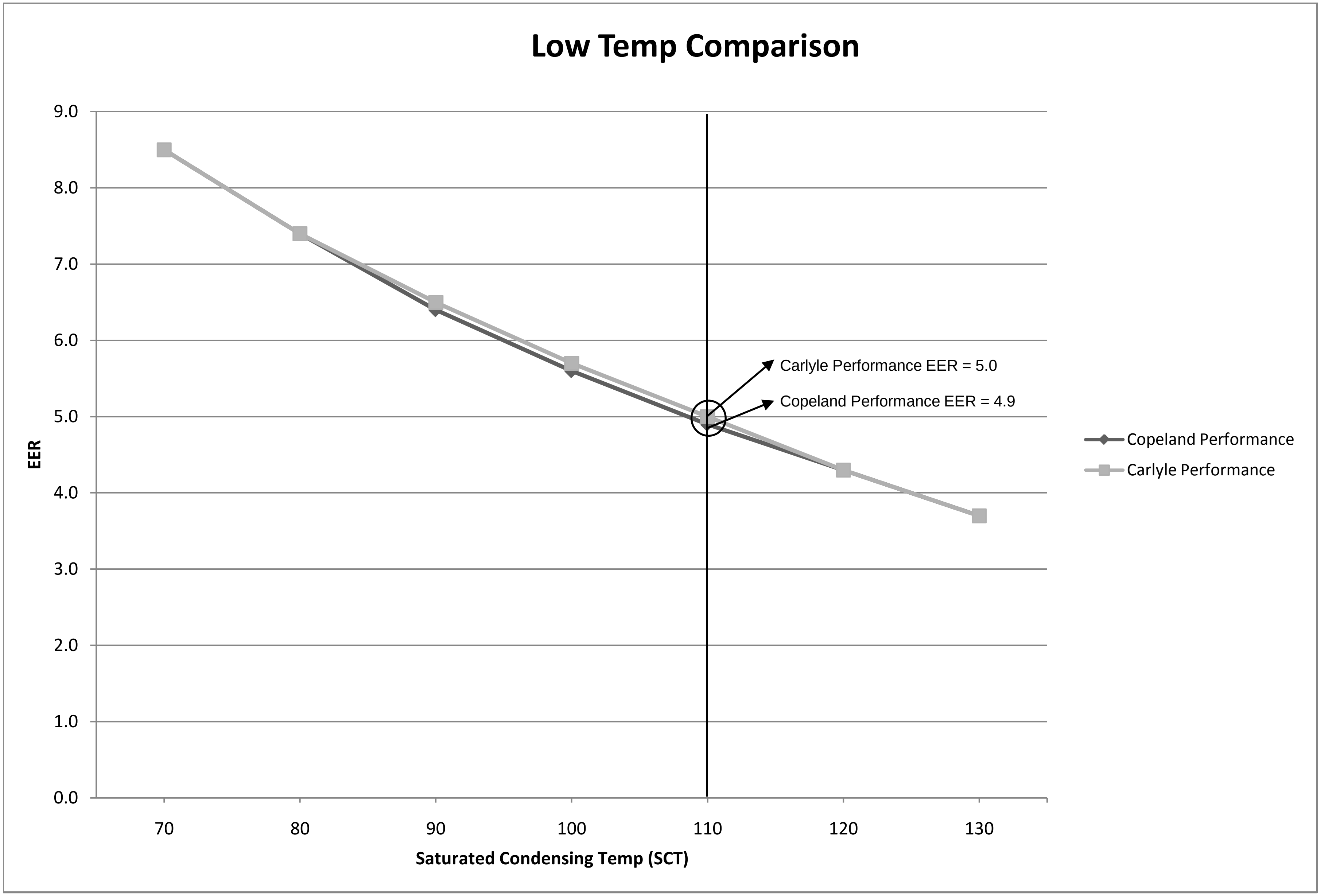
1) The low temp EER based on a typical 10 hp, Copeland Discus reciprocating semi hermetic compressor (model # 4DA3-100E). The compressor performance is at -25F SST.
2) The medium temp EER based on a typical 10 hp, Copeland Discus reciprocating semi hermetic compressor (model #3DB3-100E). The compressor 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
EER
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
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

Appendix C-2

Project Savings and Economics

PG&E Emerging Technology Study: Refrigerated Case Lighting
San Miguel Market (Stockton) Cost Summary and Payback

Project Cost Summary

The economic analysis shown below indicates the anticipated cost and savings for current market conditions. The "Payback, Energy & Maintenance" scenario includes additional maintenance savings from eliminating the need to replace fluorescent system components (as calculated elsewhere).

Quantity of Light Bars Installed:		4	(2) Philips LFM 200 side bars and (2) Philips LFM 200 center bars
Unit Cost per Light Bar:	$	186.00	Source LEDPower: for 36 LED/foot ($34/foot in high volume), plus 20% for driver, Cary Aberg, 6/25/08.
Total Material Cost:	$	744.00	
Labor Cost per Light Bar:	$	33.87	As observed, see Avoided Maintenance Cost for details.
Labor Installation Cost:	$	135.48	
Total Project Cost:	$	879.48	

Project Payback Summary

Annual Dollar Savings, Energy:	**$81.43**	**/yr**	per Energy Savings Calculation
Payback, Energy:	**10.8**	**yrs**	
Annual Avoided Maint. Cost:	**$114.24**	**/yr**	per Avoided Maintenance Cost Calculation
Total Annual Savings:	**$195.67**	**/yr**	
Payback, Energy & Maintenance:	**4.5**	**yrs**	

Simple Payback vs. Rated Life

Average Rated Life:	**50,000**	**hrs**	Source: Philips LFM 200 Technical Data Sheet
Annual Operating Hours:	**6,022**	**hrs/yr**	6.5 hours/day * 365 days/year as supported by the data collected from the measured circuit
Expected Life:	**8.3**	**yrs**	based on annual operation over useful life
Payback, Energy:	**10.8**	**yrs**	

Recap of Cost and Payback

Project Cost:	**$**	**879.48**	
Payback, Energy:		**10.8**	**yrs**
Payback, Energy & Maintenance:		**4.5**	**yrs**

San Miguel Market (Stockton) Avoided Maintenance Cost

Avoided Maintenance Cost

Replacement of fluorescent lighting systems with new LED systems will typically result in avoided maintenance costs over the life of the new LED system. The avoided maintenance cost is a result of longer rated life of LED systems compared to fluorescent lighting systems. Based on average life characteristics of the current and proposed equipment, more than 2 cycles of fluorescent lamp replacement will be avoided during the expected life of the LED system. During that period, it is predicted that a small percentage of fluorescent 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.

	Unit Labor Hours[1]	Labor Rate[2]	Unit Labor Cost	Unit Material Cost[3]	Unit Replacement Cost
GE F58WT8/841 Fluorescent Lamp	0.089	$ 80.65	$ 7.18	$ 45.90	$ 53.08
GE 2L F58T8 Ballast	0.851	$ 80.65	$ 68.63	$ 57.20	$ 125.83
Philips Affinium LED (LFM 200)	0.420	$ 80.65	$ 33.87	$ 186.00	$ 219.87

	Average Rated Life (hrs)[4]	Annual Operating Hours (hrs/yr)[5]	Annual Failure Rate[6]	Replacements per LED Life Cycle	Replacement Cost per LED Life Cycle
GE F58WT8/841 Fluorescent Lamp	20,000	6,022	30.1%	2.50	$ 132.70
GE 2L F58T8 Ballast	60,000	6,022	10.0%	0.83	$ 104.44
Philips Affinium LED (LFM 200)	50,000	6,022	12.0%	-	-

Total Unit Replacement Cost per LED life Cycle:	**$ 237.14**	
Annualized Unit Replacement Cost:	**$ 28.56**	**/yr**
Quantity of Fluorescent Units:	**4**	
Annual Avoided Maintenance Cost:	**$ 114.24**	**/yr**

[1]Labor hours for fluorescent lamp and ballast replacement per 2007 Means. Labor hours for LED lighting system as observed.
[2]Labor rate per 2007 Means for Electrician and Stockton City modifier: $ 80.65 /hr
[3]Unit Materials Cost for fluorescent systems per www.grainger.com (11/17/2008).
[3]Unit Materials Cost for LED systemsSource LEDPower: for 36 LED/foot ($34/foot in high volume), plus 20% for driver, Cary Aberg, 6/25/08.
[4]Average Rated Life per manufacturer's cut sheets for fluorescent and LED systems. See Cost & Payback Calculations.
[5]Annual Operating Hours are 6.5 hours/day * 365 days/year as supported by the data collected from the measured circuit.
[6]Annual Failure Rate = Annual Operating Hours / Average Rated Life

Project: ELECTRICITY RATE ANALYSIS - DEFINITIONS
Customer: PG&E
Facility: San Miguel Market
Building: Stockton
Utility: PG&E
Rate Schedule E-19S
Effective Date: November 12, 2008

Background

This sheet summarizes the energy and demand charges during summer and winter for peak, partial-peak, and off-peak periods for time-of-use rate sche 186 Source LEDPower: for 36 LED/foot ($34/foot in high volume), plus 20% for driver, Cary Aberg, 6/25/08.

Approach

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

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			SUMMARY BY PERIOD		
period	daily hours			days per week		hr/day	wk/yr	hr/yr	on-peak	mid peak	off-peak
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	0.14380	12.30	6.90
	partial-peak	0.09873	2.80	
	off-peak	0.05029	0.00	
WINTER:	Nov 1-April 30			
	peak	0.00000	0.00	
	partial-peak	0.08791	1.00	6.90
	off-peak	0.07748	0.00	

Project: ELECTRICITY RATE ANALYSIS - PROJECT RATE
Customer: PG&E
Facility: San Miguel Market
Building: Stockton

Utility: PG&E
Rate Schedule E-19S
Effective Date: November 12, 2008

Background

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

186 Source LEDPower: for 36 LED/foot ($34/foot in high volume), plus 20% for driver, Cary Aberg, 6/25/08.

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: Refrigerated Case Operating Hours (6:10-10:35)

SUMMER May 1-October 31 6 months

SCHEDULE						SAVINGS SCHEDULE			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	6.0	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	3.5	26.07	456			456
	-	to	2400	2	S/S	16.5	26.07	860			860
Weekday holidays which are completely off-peak:						(	3)		(18)	(21)	39

WINTER Nov 1-April 30 6 months

SCHEDULE						SAVINGS SCHEDULE					
period	daily hours			days per week		hr/day	wk/yr	hr/yr			
peak	-	to	-	5	M/F	0.0	26.07	0	0.0		
partial-peak	830	to	2130	5	M/F	13.0	26.07	1,695		1,694.6	
	-	to	-	5	M/F	0.0	26.07	0		0.0	
off-peak	2130	to	830	5	M/F	3.5	26.07	456			456.2
	-	to	2400	2	S/S	16.5	26.07	860			860.3
Weekday holidays which are completely off-peak:						(	5)		0.0	(65.0)	65.0
								TOTAL ==>	764.1	2521.0	2737.0
								% total	12.7%	41.9%	45.4%

PROJECT UTILITY RATE:

Energy Savings: 1 additional kW saved x 6,022 hrs/yr = 6,022 kWh/yr
Demand Savings: 1 kW per month

	ENERGY	DEMAND	
SUMMER	$/kW	$/kW	$/kW
period		peak	max
peak	109.88	73.80	41.40
partial-peak	88.01	16.80	0.00
off-peak	68.17	0.00	0.00
subtotal	266.06	90.60	41.40
WINTER			
period			
peak	0.00	0.00	0.00
partial-peak	143.26	6.00	41.40
off-peak	107.04	0.00	0.00
subtotal	250.30	6.00	41.40

AVERAGE RATE CALCULATION

$516.36	/yr avoided energy charges
$96.60	/yr avoided time-related demand charges
$82.80	/yr avoided nontime-related demand charges
$695.76	/yr
$0.1155	/kWh average annual electric rate INCLUDING demand *
$0.0857	/kWh average annual elec rate NOT INCLUDING demand

* correct project rate for load reducing project includes demand

EMCOR
Energy Services

Appendix D

Product Specifications

Appendix D-1

Base Case Fluorescent Lighting System

GRAINGER
FOR THE ONES WHO GET IT DONE

printed November 18, 2008

Lamp,F58t8/841-Ct,58 Watt,Med Bi-Pin

Lamp, Fluorescent, F58T8/841-CT, Lamp Shape Linear, Lamp Watts 58, 4100 Color Temp, Rated Average Life Hours 18,000, Medium BiPin (G13) Base, 85 CRI, Jacketed, Cold Temperature Application, Initial Lumens 5800, Mean Lumens 4160, Start Type Rapid, Enhanced Cool Lamp Tone, Diameter T8, 1 In (38mm), Max Overall Length 60 In, Product Contains Mercury, Refer To Applicable State Regulations for Disposition After Use. Only shipped in quantities of 24.

Grainger Item #	2PE88
Price (ea.)	**$45.90**
Brand	GENERAL ELECTRIC
Mfr. Model #	F58t8/841-Ct 58W
Ship Qty.	24
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	1.19
Usually Ships	Today
Catalog Page No.	535

Price shown may not reflect your price. Log in or register.

Additional Info

Linear Fluorescent T8 Starcoat Technology

Tech Specs

Item: Fluorescent Lamp
Lamp Shape: T8
Base: Medium Bi-Pin (G13)
Length (In.): 60
Watts: 58
Lamp Designation: F58T8/841-CT
Description/Special Features: Cold Temperature
Dia.: 1" (26mm)
Average Life (Hours): 20,000
Lamp Tone: Enhanced Cool
Color Temp.: 4100
CRI: 85
Initial Lumens: 5800
Mean Lumens: 4160
Start Type: Rapid Start
Case Quantity: 24

Notes & Restrictions

There are currently no notes or restrictions for this item.

MSDS

This item does not require a **Material Safety Data**

Optional Accessories

Box,4ft Recycling

Item #: 5KH63
Brand: RECYCLEPAK
Usually Ships: Today
Price (ea): $70.55

Box,8ft Recycling

Item #: 5KH64
Brand: RECYCLEPAK
Usually Ships: Today
Price (ea): $77.75

Ballast,F54t5 Lamps

Item #: 3CE46
Brand: ADVANCE
Usually Ships: Today
Price (ea): $55.75

Required Accessories

There are currently no required accessories for this item.

Alternate Products

Fluorescent Lamp,F58T8/835/ARTIC

Item #: 2EAJ9
Brand: GENERAL ELECTRIC
Usually Ships: 1-3 Days
Price (ea): $38.05

Repair Parts

A Repair Part may be available for this item. Visit our Repair Parts Center or contact your local branch for more information.

GRAINGER
FOR THE ONES WHO GET IT DONE

printed November 18, 2008

Ballast,Electronic,Amps 0.13 - 0.58

Ballast, Electronic, For Use With T5 Lamps, Number of Lamps 2, Voltage 120/277, Programmed Start, Amps AC .98-.43, Input Watts 113, Ballast Factor 1, Power Factor Greater Than 0.98, High Light Output, Wiring Type, Anti- Striation Control, Length 11 13/16 In, Height 1 11/16 In, Width 1 3/16 In, Number of F54T5 Lamps 1 or 2

Grainger Item #	2FPJ6
Price (ea.)	**$57.20**
Brand	GENERAL ELECTRIC
Mfr. Model #	GE254MVPS90-D
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	1.82
Usually Ships	1-3 Days
Catalog Page No.	N/A

Price shown may not reflect your price. Log in or register.

Additional Info

There is currently no additional information for this item.

Tech Specs

Item: Electronic Ballast
Lamp Type: Fluorescent
Start Type: Programmed
Number of Lamps: 2
Voltage: 120/277
Amps AC: 0.98 - 0.43
Input Watts: 116 - 114
Min. Starting Temp. (F): 0
Ballast Factor: 1.00
Power Factor: Greater Than0.98
Special Features: Anti-Striation Control
Light Output: High
Ballast Family: Ultrastart
Length (In.): 11 13/16
Height (In.): 1 11/16
Width (In.): 1 3/16
Dimension Reference: G14
Number of F50BX Lamps: 1 or 2
Number of F54T5 Lamps: 1 or 2
Number of F55BX Lamps: 1 or 2
Number of F58T8 Lamps: 1 or 2
Package Quantity: 1

Notes & Restrictions

There are currently no notes or restrictions for this item.

Optional Accessories

Ballast Recycling Kit

Item #: 5KH66
Brand: RECYCLEPAK
Usually Ships: Today
Price (ea): $121.75

Alternate Products

There are currently no alternate products for this item.

Repair Parts

A Repair Part may be available for this item. Visit our Repair Parts Center or contact your local branch for more information.

MSDS

This item does not require a **Material Safety Data Sheet (MSDS).**

Required Accessories

There are currently no required accessories for this item.

Appendix D-2

Replacement LED Lighting System

Lighting food. Brightening faces.

Philips Affinium LED modules LFM 200
for refrigerated display cases

Affinium LED modules LFM 200 are designed to replace traditional tubular fluorescent lamps inside vertical glass-door refrigerated display cases.

The modules include the latest LED technologies and are driven by a 24VDC Xitanium LED power driver.

The new LFM 200 modules offer the following key benefits:

- An excellent Total Cost of Ownership with attractive payback times.
- A dramatic improvement in visibility of both the merchandise on display as well as the entire display case.
- Significant reduction in energy consumption, and waste, and the elimination of hazardous substances such as mercury and lead.

PHILIPS

sense and simplicity

Affinium LED lighting

The Affinium LED lighting system for refrigerated display cases includes: Affinium LED modules LFM 200, 24VDC Xitanium LED power drivers, and mounting extrusions.

About Affinium LED modules LFM 200

The LFM 200 module is suitable for full-height glass door refrigerated display cases and available in 59" and 67" lengths.

Both lengths are available in three versions:

- a center module
- a side 1 module and
- a side 2 module.

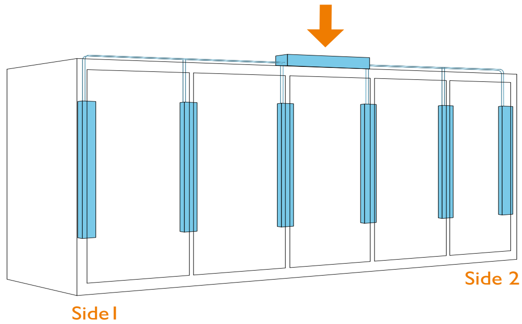
The side 1 or 2 module can be placed on either side of the case, depending on the wiring scheme followed.

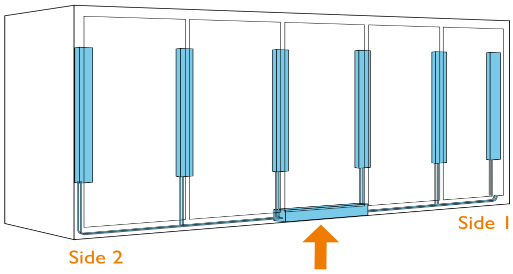
Connections at the top of the freezer

If the electrical wires are fed through the top of the case, please install the side 1 module at the left side and the side 2 module at the right side of the case.

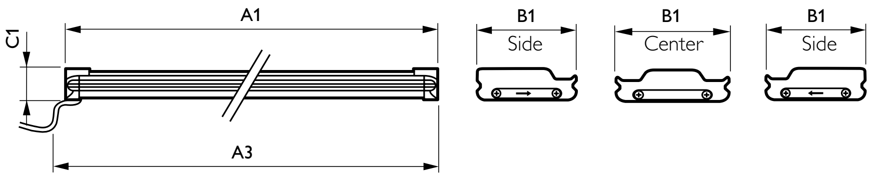
Connections at the bottom of the freezer

If the electrical wires are fed through the bottom of the case, please install the side 2 module at the left side and the side 1 module at the right side of the case.





Affinium LED modules	Dimensions (in)			
	A1	A3	B1	C1
LFM 200 59" center modules	59.06	59.45	2.20	0.94
LFM 200 59" side 1 modules	59.06	59.45	1.93	0.94
LFM 200 59" side 2 modules	59.06	59.45	1.93	0.94
LFM 200 67" center modules	66.93	67.32	2.20	0.94
LFM 200 67" side 1 modules	66.93	67.32	1.93	0.94
LFM 200 67" side 2 modules	66.93	67.32	1.93	0.94



Color temperature

Cool White (CW) LED modules have a correlated color temperature (CCT) of 5600 ± 600K.
Neutral White (NW) LED modules have a correlated color temperature (CCT) of 4100 ± 600K.
The optical design of Philips Affinium LED modules ensures that the adjacent LEDs in one module are optimally mixed in order to minimize color differences.

Lighting levels and energy savings

Our products are available with two different lighting levels:

1. A standard lighting level of 700 lux
2. A high lighting level of 1100 lux.

The 700 lux level offers energy savings up to 75% with improved lighting levels. The 1100 lux level offers maximum aesthetics for the presentation of merchandise, yet reducing the energy consumption by more than 55%. Both levels offer a superior uniformity enabling a much better visual impression of the merchandise on display and the entire cooler and freezer sections.

Affinium LED modules, 59" length

Type	Power nominal W	Color temperature K	Color rendering index CRI
Standard lighting level 700 lux			
LFM 200 59" center CW	25	5000-6200	≥70
LFM 200 59" side 1 CW	15	5000-6200	≥70
LFM 200 59" side 2 CW	15	5000-6200	≥70
LFM 200 59" center NW	25	3500-4700	≥70
LFM 200 59" side 1 NW	15	3500-4700	≥70
LFM 200 59" side 2 NW	15	3500-4700	≥70
High lighting level 1100 lux			
LFM 200 59" center NW	35	3500-4700	≥70
LFM 200 59" side 1 NW	22	3500-4700	≥70
LFM 200 59" side 2 NW	22	3500-4700	≥70

Affinium LED modules, 67" length

Type	Power nominal W	Color temperature K	Color rendering index CRI
Standard lighting level 700 lux			
LFM 200 67" center CW	31	5000-6200	≥70
LFM 200 67" side 1 CW	20	5000-6200	≥70
LFM 200 67"side 2 CW	20	5000-6200	≥70
LFM 200 67" center NW	31	3500-4700	≥70
LFM 200 67" side 1 NW	20	3500-4700	≥70
LFM 200 67"side 2 NW	20	3500-4700	≥70
High lighting level 1100 lux			
LFM 200 67" center NW	44	3500-4700	≥70
LFM 200 67" side 1 NW	28	3500-4700	≥70
LFM 200 67" side 2 NW	28	3500-4700	≥70

* Notes on lighting levels and energy savings:

Lighting levels are measured by a CCD camera at five equally spread horizontal positions in the center of the freezer with a 10 cm distance between the back of the module and the front of the merchandise.

Values for nominal power and lighting levels can deviate by 20%, measured at -20 °C. Due to insufficient data points the values are best estimations.

Lifetime

The lifetime of the modules is rated at 50 000 hours (70% lumen maintenance).

Temperature

Operating temperature (performances):	$T_{operating}$	min -13 F / max +50 F
Safety temperature (operating, no defects)	T_{safety}	min -22 F / max +86 F
Storage temperature	$T_{storage}$	min -22 F / max +140 F

Enhanced safety

When used with a Safety Extra Low Voltage (SELV) 24VDC energy-limited class-2 Xitanium LED driver, safety is ensured even if wiring of units becomes damaged.

Compliances and approvals

Philips Affinium LED modules comply with all the applicable legislation, such as RoHS (Restriction of Hazardous Substances) and WEEE (Waste Electrical and Electronic Equipment). This means all components used are lead-free and soldered in a lead-free soldering process (EU directive 2002/95/EC).

- ENEC
- CE
- Product safety, class III
- RoHS compliant
- WEEE
- EU directive 2002/95/EC
- UL
- NSF

Ordering details

Affinium LED modules, 59" length

Type	Quantity per pack	Ordering code 12 NC
Improved lighting level 700 lux		
LFM 200 1500mm (59") center 25W CW	1	9290 001 37113
LFM 200 1500mm (59") side 1 15W CW	1	9290 001 37213
LFM 200 1500mm (59") side 2 15W CW	1	9290 001 37313
LFM 200 1500mm (59") center 25W NW	1	9290 001 37413
LFM 200 1500mm (59") side 1 15W NW	1	9290 001 37513
LFM 200 1500mm (59") side 2 15W NW	1	9290 001 37613
High lighting level 1100 lux		
LFM 200 1500mm (59") center 35W NW	1	9290 004 55813
LFM 200 1500mm (59") side 1 22W NW	1	9290 004 55913
LFM 200 1500mm (59") side 2 22W NW	1	9290 004 56013

Affinium LED modules, 67" length

Type	Quantity per pack	Ordering code 12 NC
Improved lighting level 700 lux		
LFM 200 1700mm (67") center 31W CW	1	9290 001 38313
LFM 200 1700mm (67") side 1 20W CW	1	9290 001 38413
LFM 200 1700mm (67") side 2 20W CW	1	9290 001 38513
LFM 200 1700mm (67") center 31W NW	1	9290 001 38613
LFM 200 1700mm (67") side 1 20W NW	1	9290 001 38713
LFM 200 1700mm (67") side 2 20W NW	1	9290 001 38813
High lighting level 1100 lux		
LFM 200 1700mm (67") center 44W NW	1	9290 004 56413
LFM 200 1700mm (67") side 1 28W NW	1	9290 004 56513
LFM 200 1700mm (67") side 2 28W NW	1	9290 004 56613

Retrofit Mounting Extrusions

Type	Part Number
LFM200 60" Center Mounting Extrusion	LFM200EXT60INCRM
LFM200 72" Center Mounting Extrusion	LFM200EXT72INCRM
LFM200 60" Side Mounting Extrusion (both sides)	LFM200EXT60INSDM
LFM200 72" Side Mounting Extrusion (both sides)	LFM200EXT72INSDM

July 2008

www.philips.com/led

Appendix D-3

Reach-in Freezer Case

HUSSMANN® IMPACT™ Merchandisers

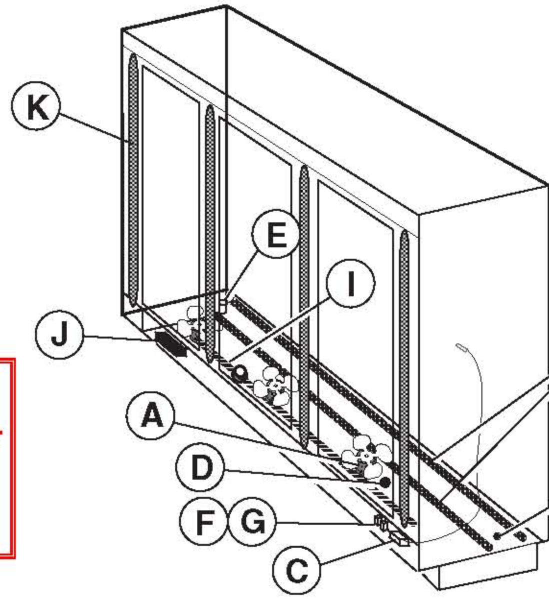
RL with INNOVATOR Doors

Technical Data Sheet

P/N 0425644_M

NSF® Certified

July 2007



Warning:
Terminal block NOT for case-to-case wire connection!

We reserve the right to change or revise specifications and product design in connection with any feature of our products. Such changes do not entitle the buyer to corresponding changes, improvements, additions or replacements for equipment previously sold or shipped.

Item Part # Description Wiring Item #

Fan Assemblies, and Thermostats

A. **12W Standard** Fan Assembly (1)
- 0047000 Fan Motor, Evaporator (MO.4410103)
- 0461805 Fan Blade (FB.4780446)

12W Optional Energy Efficient Fan Assembly (1)
- 0477655 Fan Motor, Evaporator (MO.4410546)
- 0461805 Fan Blade (FB.4780446)

B. 0474033 Standard Non-adjustable Defrost Thermostat (CT.4440726) (2)

C. Optional Adjustable Refrigeration Thermostat (3)

D. 0344662 Defrost Limit Thermostat (CT.4440261) (4)

E. 0461814 Relay Control Thermostat or Fan and Anti-sweat Heater Thermostat (CT.4481296) (5)

Relays

F. 0342598 Anti-Sweat Control Relay (120V) (RL.4480238) (6)

G. 0342599 Fan Control Relay (208V) (RL.4480237) (7)

Heaters

H. Electric Defrost Heaters – Front (208V) (8)
- 0484312 (1) 1 Door Models (HE.4850632)
- 0441755 (1) 2 Door Models (HE.4850346)
- 0441756 (1) 3 Door Models (HE.4850337)
- 0441757 (1) 4 Door Models (HE.4850347)
- 0441758 (1) 5 Door Models (HE.4850323)

NOTE: Revision M adds more LED lighting data.

Item Part # (Qty) Description Wiring Item #

Heaters (Continued)

H. Electric Defrost Heaters — Rear (208V) (8)
- 0484313 (1) 1 Door Models (HE.4850634)
- 0463891 (1) 2 Door Models (HE.4850358)
- 0463892 (1) 3 Door Models (HE.4850359)
- 0463893 (1) 4 Door Models (HE.4850360)
- 0463894 (1) 5 Door Models (HE.4850361)

I. Drain Pan Heater — Electric & KoolGas (120V) (9)
- 0489708 (1) 1 Door Models (HE.4850643)
- 0387036 (1) 2 Door Models (HE.4850239)
- 0387037 (1) 3 Door Models (HE.4850240)
- 0387038 (1) 4 Door Models (HE.4850241)
- 0387039 (1) 5 Door Models (HE.4850242)

Lamps and Ballasts

J.
- 0430329 1 Lamp Ballast (BA.4480341)
- 0430330 2 Lamp Ballast (BA.4480342)
- 0454319 3 Lamp Ballast (BA.4480601)
- 0424649 Export Ballast (BA.0424649)

K. Standard Fluorescent Lamp *Replace with like fixtures*

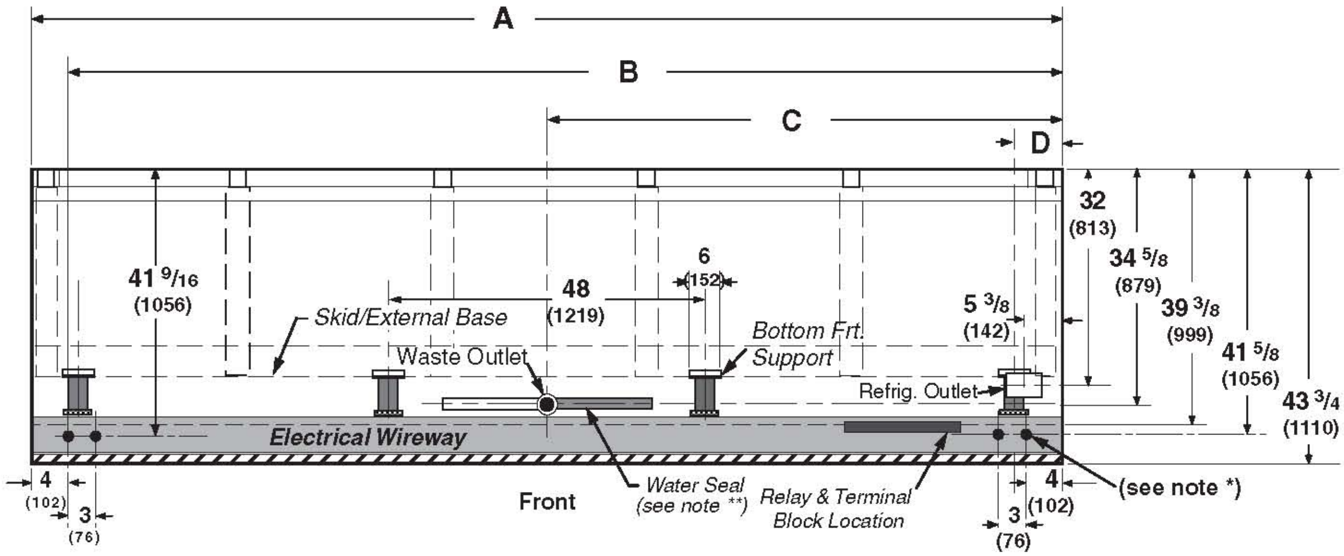
NOTE: For LED lighting parts contact your Hussmann service representative at 1-800-922-1919. Please have your model and serial number available.

Refer to Innovator Reach-In Glass Door Installation and Service ***manual, P/N 0425683, for Innovator II door and frame replacement parts.***

Reach-In
1, 2, 3, 4 & 5 Door

RL-RM-RMF
Plan View

Dimensions shown as in. & (mm).

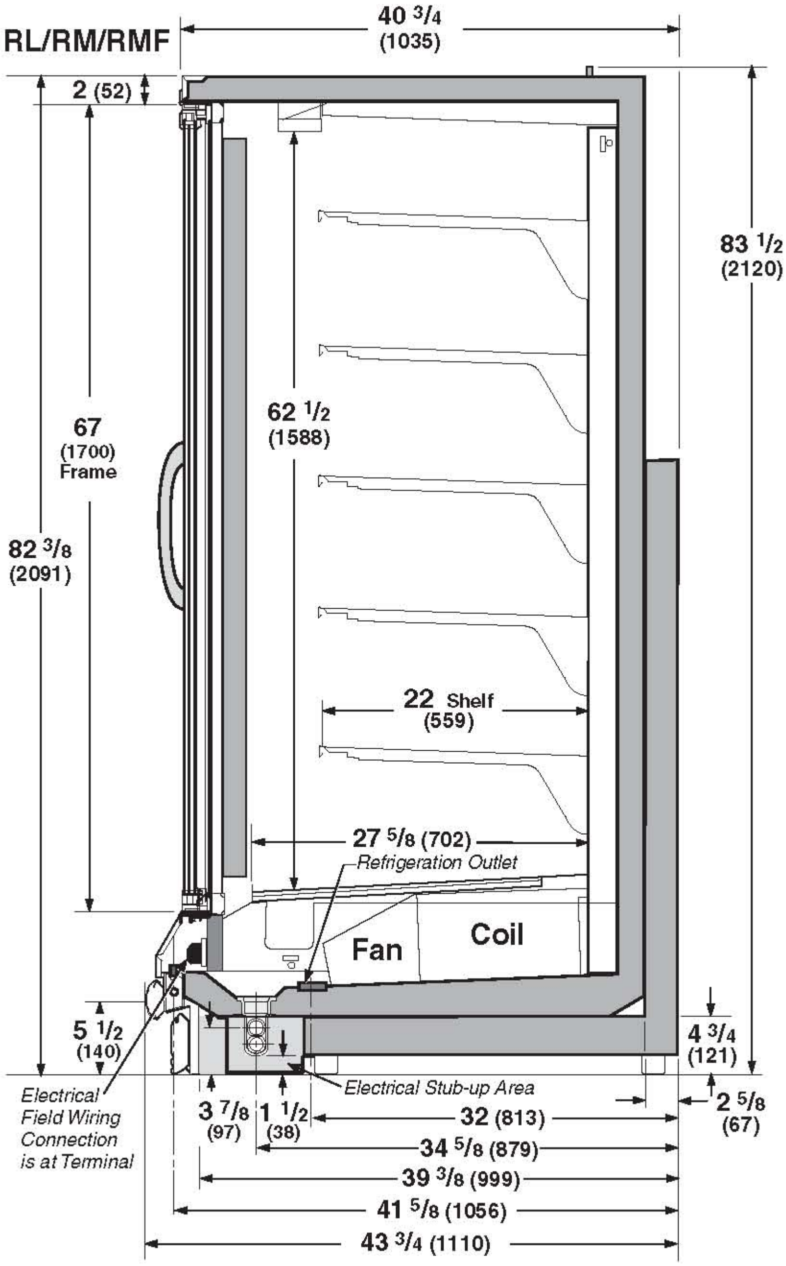


	1 Dr	2 Dr	3 Dr	4 Dr	5 Dr
General					
(A) Case Length (without ends or partitions)	31 1/2 (800)	62 (1575)	92 1/2 (2350)	122 7/8 (3121)	153 3/8 (3896)
Maximum O/S dimension of case back to front *(Includes bumper)*	43 3/4 (1111)	43 3/4 (1111)	43 3/4 (1111)	43 3/4 (1111)	43 3/4 (1111)
Back of case to rear of splashguard	39 3/8 (1000)	39 3/8 (1000)	39 3/8 (1000)	39 3/8 (1000)	39 3/8 (1000)
Width of Skidrail	4 1/2 (114)	4 1/2 (114)	4 1/2 (114)	4 1/2 (114)	4 1/2 (114)
Width of Bottom Front Support	6 (152)	6 (152)	6 (152)	6 (152)	6 (152)
Stub-up area between front skidrail and splashguard	6 3/8 (162)	6 3/8 (162)	6 3/8 (162)	6 3/8 (162)	6 3/8 (162)
Electrical Service					
RH end of case to the center of nearest knockout	4 (102)	4 (102)	4 (102)	4 (102)	4 (102)
(B) RH end of case to the center of LH knockout	27 1/2 (698)	58 (1473)	88 1/2 (2248)	118 7/8 (3019)	149 3/8 (3794)
Back O/S of case to center of knockout	41 5/8 (1058)	41 5/8 (1058)	41 5/8 (1058)	41 5/8 (1058)	41 5/8 (1058)
** NOTE: Electrical Field Wiring Connection Point is at terminal.*					
Waste Outlet					
(C) Right end of case to center of waste outlet	15 3/4 (400)	23 3/4 (603)	54 1/4 (1378)	46 1/4 (1175)	76 5/8 (1946)
Back O/S of case to center of waste outlet	34 5/8 (879)	34 5/8 (879)	34 5/8 (879)	34 5/8 (879)	34 5/8 (879)
Water Seal					
Edge of water seal to center of waste outlet	11 (279)	11 (279)	11 (279)	11 (279)	11 (279)
Outside diameter of drip piping	1 1/4 (32)	1 1/4 (32)	1 1/4 (32)	1 1/4 (32)	1 1/4 (32)
*** NOTE: Field installed water seal outlets, tees, and connectors are shipped with case*					
Refrigeration Outlet					
RH end of case to center of RH refrigeration outlet	5 3/8 (137)	5 3/8 (137)	5 3/8 (137)	5 3/8 (137)	5 3/8 (137)
Back O/S of case to center of refrigeration outlet	32 (813)	32 (813)	32 (813)	32 (813)	32 (813)
(D) Outside bottom front supports from end of case	6 3/4 (170)	6 3/4 (170)	6 3/4 (170)	6 3/4 (170)	6 3/4 (170)
Center bottom front support from Centerline	NA	24 (610)	24 (610)	24 (610)	24 (610)
Distance between Center and Outside supports will vary					

Reach-in 2, 3, 4 and 5 Door Models

Impact RL
With INNOVATOR Doors
Frozen Food & Ice Cream

Dimensions shown as in. & (mm).



REFRIGERATION DATA

Note: This data is based on store temperature and humidity that does not exceed 75°F and 55% R.H.

	2, 3, 4, 5 Door		1 Door	
	FF	**IC**	**FF**	**IC**
Discharge Air (°F)	–5	–12	2	–5
Evaporator (°F)	–11	–19	–11	–19
Unit Sizing (°F)	–14	–22	–14	–22
Btu/hr/Door*				
Parallel	1300	1370	1390	1470
Conventional	1325	1400	1420	1590

*Optional LED lighting reduces refrigeration load by 100 Btu/hr/Door.

DEFROST DATA

ALL	FF	IC
Frequency (hr)	24	24
Defrost Water (lb/Dr/day)	**1.2**	**1.2**

(**± 15%** based on case configuration and product loading.)

ELECTRIC	FF	IC
Temp Term (°F)	48°	48°
Failsafe (minutes)	45	45

GAS		
Duration **(minutes)**	20	20

OFFTIME Not Recommended

CONVENTIONAL CONTROLS

Low Pressure Backup Control

	FF	IC
CI/CO (Temp °F)**	–18°/–34°	– 26°/–45°

Indoor Unit Only, Pressure Defrost Termination (Temp °F)**
Not Recommended
****Use a Temperature Pressure Chart to determine PSIG conversions.**

PHYSICAL DATA

Drip Pipe (in.)	1 1/4
Liquid Line (in.)	3/8
Suction Line (in.)	7/8

Estimated Charge (lb)***

1Dr	0.9	**4Dr**	3.6
2Dr	1.8	**5Dr**	4.6
3Dr	2.7		

***This is an average for all refrigerant types. Actual refrigerant charge may vary by approximately half a pound.

Length Added to Lineup by each	
Standard End (in.)	2
Optional End with Window (in.)	1 1/2
Optional Partition (in.)	1 1/2

NSF Certification

These merchandisers are manufactured to meet ANSI /National Sanitation Foundation (NSF®) Standard #7 requirements.

Impact **RL**
With INNOVATOR Doors
Frozen Food & Ice Cream

Hussmann recommends against frame heater cycling with *Innovator* doors to prevent door seals from freezing to the frames and tearing.

Electrical Data

Number of Fans—12W	1	2	3	4	5					
	Amperes					Watts				
Merchandiser	**1Dr**	**2Dr**	**3Dr**	**4Dr**	**5Dr**	**1Dr**	**2Dr**	**3Dr**	**4Dr**	**5Dr**
Evaporator Fan										
120V 60Hz Standard	0.65	1.30	1.95	2.60	3.25	50	100	150	200	250
120V 50Hz Standard	0.75	1.50	2.25	3.00	3.75	57	114	171	228	285
220V 60Hz Export	NA	0.66	0.99	1.32	1.65	NA	100	150	200	250
220V 50Hz Export	NA	0.76	1.14	1.52	1.90	NA	114	171	228	285
120V 60Hz Energy Efficient	0.30	0.60	0.90	1.20	1.50	18	36	54	72	90
220V 60Hz Energy Efficient	NA	0.30	0.45	0.60	0.75	NA	36	54	72	90
Door Anti-sweat Heaters (on fan circuit)										
120V 50/60Hz Standard	0.77	1.54	2.31	3.08	3.86	92	185	278	370	463
220V 50/60Hz Export	NA	0.84	1.26	1.68	2.10	NA	185	278	370	463
Frame Anti-sweat Heaters (on fan circuit)										
120V 50/60Hz Standard	0.39	0.78	1.18	1.57	1.97	47	94	141	188	236
220V 50/60Hz Export	NA	0.43	0.64	0.85	1.07	NA	94	141	188	236
Minimum Circuit Ampacity										
120V 60Hz Standard	3.01	3.82	5.64	7.45	9.28					
120V 50Hz Standard	3.01	4.02	5.94	7.85	9.78					
220V 60Hz Export	NA	2.13	3.09	4.05	5.02					
220V 50Hz Export	NA	2.23	3.24	4.25	5.27					
120V 60Hz Energy Efficient	NA	3.12	4.59	6.05	7.53					
220V 60Hz Energy Efficient	NA	1.77	2.55	3.33	4.12					
Maximum Over Current Protection 120V	**20**	**20**	**20**	**20**	**20**					
Maximum Over Current Protection 220V	15	15	15	15	15					
Defrost										
Drain Heaters (120V)	1.67	0.63	1.25	2.00	2.57	200	75	150	240	300
(Export: 220V 50 hz)	NA	0.34	0.76	1.22	1.53	NA	84	168	269	336
208V Electric Defrost	2.88	6.72	10.08	13.46	16.82	600	1400	2100	2800	3500
(Export: 220V 50 hz)	NA	7.11	10.66	14.24	17.79	NA	1564	2345	3133	3914
Standard Vertical Lighting	**1Dr**	**2Dr**	**3Dr**	**4Dr**	**5Dr**	**1Dr**	**2Dr**	**3Dr**	**4Dr**	**5Dr**
Innovator* Doors (120V)	1.00	1.50	2.00	2.50	3.00	120	180	240	300	360
(Export: 220V 50 hz)	NA	0.84	1.12	1.40	1.68	NA	185	246	308	370
Optional LED Lighting (120V) Gelcor	0.58	0.87	1.16	1.45	1.74	70	105	140	174	209
Optional LED Lighting (120V) Hussmann Always*Bright™	0.41	0.73	0.17	1.36	1.55	50	89	140	164	187

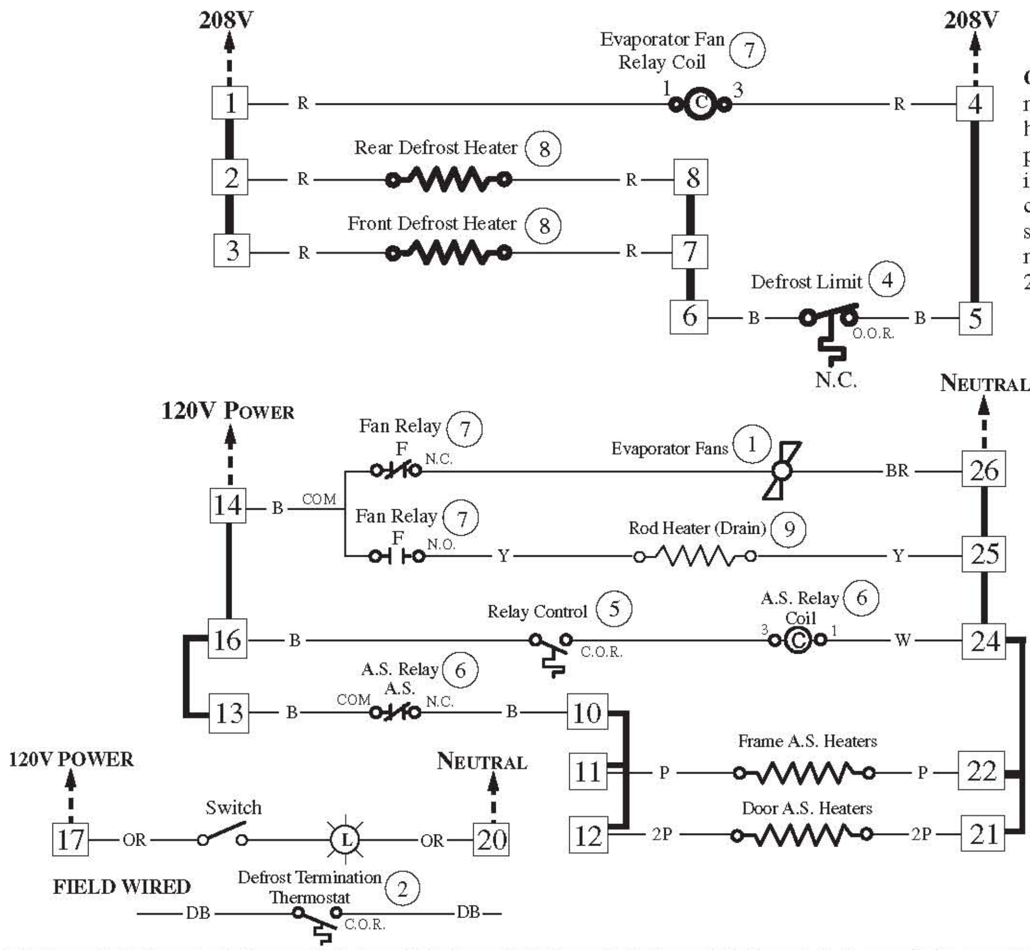
* *Innovator* or *Innovator II*

Fan and Heater Circuits - Electric Defrost (standard)
Low Temperature

CIRCLED NUMBERS = PARTS LIST ITEM NUMBERS

R = Red P = Purple 2P = Purple (2 Bands) DB = Dark Blue B = Black
BR =Brown Y =Yellow OR = Orange W = White

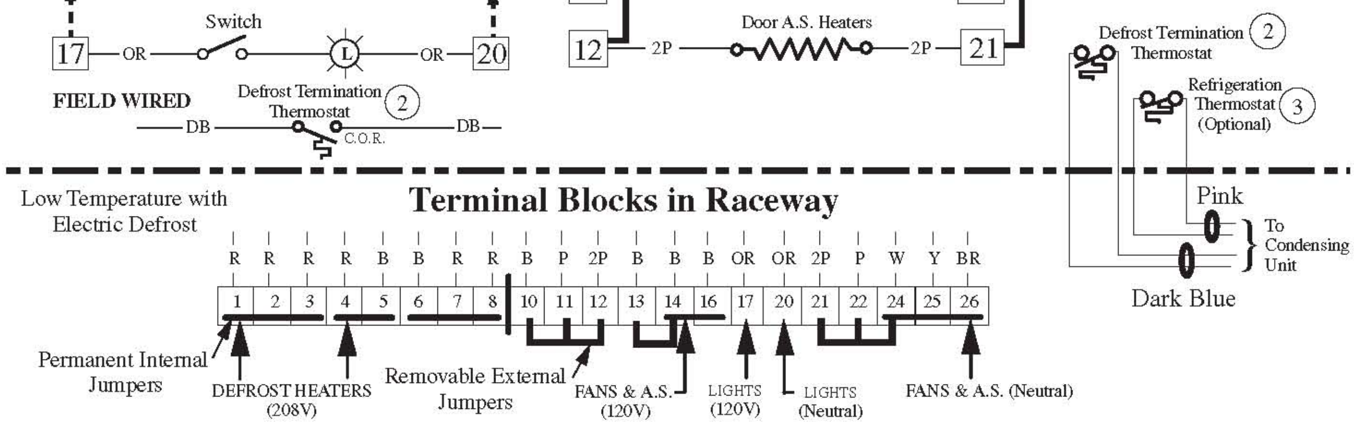
THESE ARE MARKER COLORS (WIRE MAY VARY.)



CAUTION: When multiplexing merchandisers equipped with defrost heaters, if branch circuit overcurrent protection is larger than the individual merchandiser's defrost circuit load, then additional supplemental overcurrent protection may be required per NEC Articles 210 and 240.

Refer to *Innovator Reach-In Glass Door, Installation and Service* manual, P/N 0425683, for ***Innovator*** door and frame replacement parts.

Terminal Blocks in Raceway



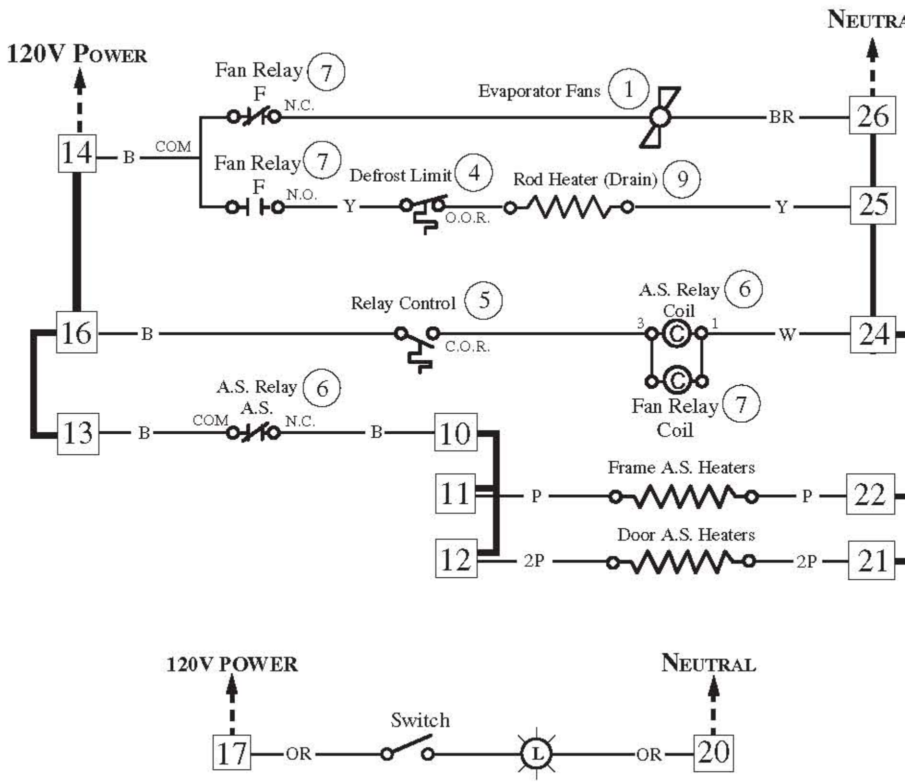
Electric Defrost Sequence - Low Temperature

1. Power from the defrost contactor energizes Defrost Heaters and 208V Evaporator Fan Relay Coil (7). Relay Contacts open the fan circuit and energizes the Drain Pan Heater.
2. If the Defrost Heater raises internal air temperature above 90°F, the Defrost Limit Thermostat (4) will open.
3. Temperature rise of the evaporator closes the Relay Control Thermostat (5) at about 35°F, energizing 120V A.S. Relay Coil (6). This relay's contacts open the Frame and Door Heater Circuits.
4. When Defrost Termination Thermostat ends defrost period, the defrost contactor opens the Defrost Heater and Evaporator Fan Relay Coil Circuits. The Drain Pan Heater goes off and fans are on.
5. Temperature fall of the evaporator opens the Relay Control Thermostat (5) at about 20°F, de-energizing 120V A.S. Relay Coil (6). A.S. Relay Contacts close the Frame and Door Heater Circuits.

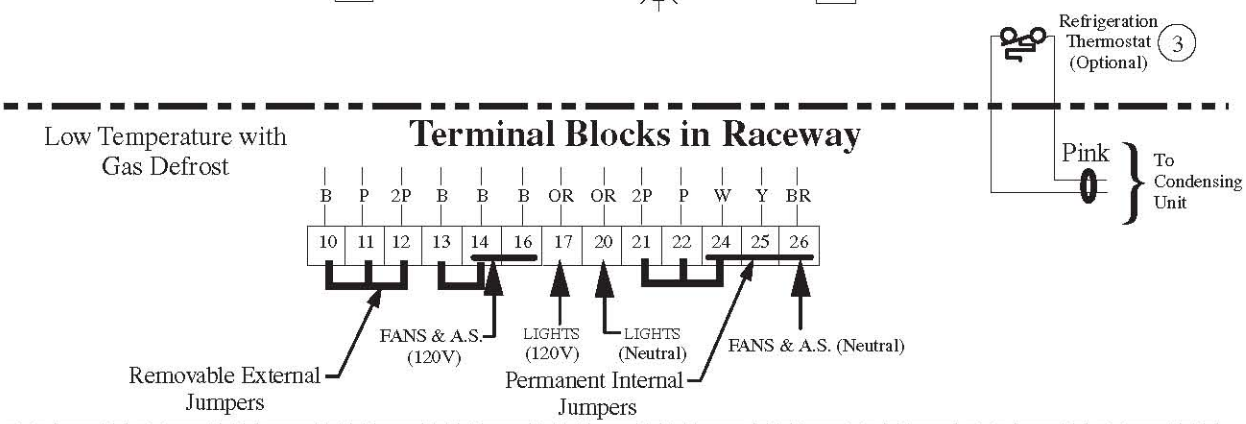
Fan and Heater Circuits - Gas Defrost (optional)
Low Temperature

CIRCLED NUMBERS = PARTS LIST ITEM NUMBERS

R = Red   P = Purple   2P = Purple (2 Bands)   DB = Dark Blue   B = Black
BR = Brown   Y = Yellow   OR = Orange   W = White
THESE ARE MARKER COLORS (WIRE MAY VARY.)



Refer to *Innovator Reach-In Glass Door, Installation and Service* manual, P/N 0425683, for ***Innovator*** door and frame replacement parts.



Gas Defrost Sequence - Low Temperature

1. Defrost vapor enters evaporator causing a rise in temperature. At about 35°F the Control Relay Thermostat (5) closes the Fan Relay Coil (7) and Control Relay Coil (6) circuit. The Coil opens the Fan, Door Heater, and Frame Heater circuits, while energizing the Drain Pan Heater (9).
2. If the Drain Pan Heater (9) raises internal air temperature above 90°F, the Heater Limit Thermostat (4) will open.
3. When the defrost timer ends a defrost period, the evaporator temperature will start to fall. At about 20°F, the Control Relay Thermostat will open, de-energizing the Control Relay Coil and Fan Relay Coil (7). Control and Fan Relay's will open the Drain Pan Heater circuits, and will close the Fan, Door Heater, and Frame Heater circuits.

EMCOR
Energy Services

Appendix E

Feedback Survey Form

CUSTOMER FEEDBACK SURVEY –
REFRIGERATED CASE LIGHTING TEST: SAN MIGUEL MARKET

DEPARTMENT/POSITION ______________________________ DATE _____________

NAME (Optional) ____

A change was recently made to some of the display lighting in one freezer case at this location. Please fill out this survey form in order to provide feedback about the lighting system.

For the questions below, <u>circle the response that most closely matches your answer</u>. 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 — 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 recommend it

1 2 3 4 5 6 7 8 9 10

Comments: ____