LED Retail Refrigerated / Freezer Case Lighting Demonstration

ET09SDGE0007

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Prepared for:

SDGE
A Sempra Energy utility®

Prepared by:

Emerging Technologies Associates, Inc.

Preface

PROJECT TEAM

This project is sponsored by San Diego Gas & Electric's (SDG&E®) Emerging Technologies Program (ETP), with Abdullah Ahmed as the project manager. Tory Bingham was the contact and project manager for Supervalu Albertsons (Albertsons). Daryl DeJean (daryldejean@gmail.com) of Emerging Technologies Associates, Inc. (ETA) provided technical consulting, data analysis, coordination of all parties involved, and finalized the report.

DISCLAIMER

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ACKNOWLEDGEMENTS

SDG&E® and ETA would like to acknowledge Albertsons for their cooperation in the project. Without their participation, this demonstration project would not have been possible.

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Abbreviations and Acronyms

CCT Correlated Color Temperature

DOE Department of Energy

EPA Environmental Protection Agency

ETA Emerging Technologies Associates, Inc.

ETP Emerging Technologies Program

FC Foot Candle

FT Feet

GWh Gigawatt hours

K Kelvin

kWh Kilowatt hours

L/W Lumens per Watt

LED Light Emitting Diode

NCI Navigant Consulting Inc.

PNNL Pacific Northwest National Laboratory

RPI Rensselaer Polytechnic Institute

SDG&E® San Diego Gas & Electric

SSL Solid State Lighting

SQFT Square Feet

T8 Tubular

UL Underwriters Laboratory

W Watts

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Executive Summary

This report summarizes an LED retail supermarket refrigerated/freezer display case assessment project conducted to study the applicability of LED in the retail supermarket sector. In this demonstration project, a light emitting diode (LED) source was installed to replace T8 fluorescent lighting in two freezer (low temperature) cases and one refrigerated (medium temperature) case at Albertsons supermarket in San Clemente, California. Typically, freezer case layouts consist of three or five doors each; a total of four and six lamps respectively since adjoining doors share the center lamp. The project involved replacing the existing lighting, a quantity of 112 5-ft F40T8 fluorescent lamps and associated solid-state electronic ballasts which provided approximately 60 – 70 L/W, with a quantity of 112 customized LED linear light bars which provided 35 – 38 L/W. The suitability of the new technology was determined by energy and power usage measurements, lighting performance characteristics, qualitative satisfaction, and economic factors.

On average, supermarkets in the US use approximately 50 kWh of electricity per sqft per year, at an average annual energy cost of more than $4 per sqft. Refrigeration and lighting account for over 50% of the energy used in supermarkets. In the retail supermarket sector, lighting is used to enhance shoppers' experience by highlighting products and creating positive visual impressions.

This project involved the demonstration of 112 LED linear light bars. In this application, for every 40 W linear fluorescent lamp removed, one LED linear light bar was installed. A high efficiency power supply meeting all UL and other applicable standards was replaced existing solid state electronic ballasts. The LED linear light bar test resulted in an average draw of 20.8 W, roughly 53% (23.6 W) less than the linear T8 fluorescent fixture and associated solid state electronic ballast. With an estimated 6,916 annual hours of operation, annual electrical savings are estimated to be approximately 163.2 kWh per fixture. Measurements per lamp from the study are tabulated in Table 1 below.

Table 1: Per Lamp Potential Demand and Estimated Energy Savings

Lamp Type	Average Power (W)	Power Savings (W)	Annual Energy Savings (kWh)
T8 Fluorescent – Base Case (0.9 BF)	44.4	-	-
LED linear light bar	20.8	23.6 (53%)	163.2

Illuminance measurements were taken to determine the difference in "intensity" between the T8 fluorescent and LED linear light bar. Measurements in each test area indicated substantially less values (39%) for illuminance for the LED as compared to the baseline T8 fluorescent source. It was noted that the consistency of the lighting from case to case was more uniform with the LED system than with the fluorescent system. Of special note is the demand savings for the compressor load of (19%) may be realized as a direct result of the reduction in compressor load requirements associated with the reduced heat gain from the LED lighting to the refrigerated space.

The rated correlated color temperature (CCT) of the LED lamps (4,100 K) was on average 600 K higher than the baseline fluorescent lamps (3,500 K).

At the time of this report, due to the as yet undemonstrated useful life of these LED lamps, economic and reliability claims are based on the best available information from the manufacturer and U.S. Department of Energy (DOE) reports.

Even with the significant energy savings of the LED linear light bars, simple payback was quite long – 11.9 years. This payback does not include maintenance or the savings on the refrigeration system due to the impact of the LED lighting system. Qualitatively, the LED lamps tested were adequate to replace the baseline lamps in this demonstration as learned from the customer survey conducted and discussed in the Lighting Performance – Customer Acceptance section.

Table 2: Simple Payback Economics

Lamp Type	Incremental Cost ($)	Annual Savings ($)	Simple Payback (years)
T8 Fluorescent	---	---	---
LED linear light bar (two LED light bars per door)	276	23.28	11.9

Project Background

PROJECT OVERVIEW

The LED Refrigerated/Freezer Case Lighting Demonstration project studied the applicability of LED lamps used to provide display case lighting in the supermarket sector. T8 fluorescent lamp systems were replaced with new LED linear light bar systems at the retail supermarket store, Albertsons, located in San Clemente, CA. The applicability of the technology was determined by energy and power usage, qualitative assessment of end user's satisfaction, lighting performance, and economic factors.

This project was conducted as part of the Emerging Technologies Program of San Diego Gas & Electric. The Emerging Technologies Program is an information-only program that seeks to accelerate the introduction of innovative energy efficient technologies applications. The information includes verified energy savings and demand reductions, market potential and market barriers, incremental cost, and the technology's life expectancy.

TECHNOLOGICAL OVERVIEW

The LED Refrigerated/Freezer Case Lighting Demonstration project focused on quantifying the energy savings potential and comparing the brightness and light quality (color) of LED and fluorescent freezer case lighting systems in situ application.

At the time of this assessment, LEDs are showing promise in retail supermarket lighting based on their potential for reduced energy consumption. There are also additional benefits specific to retail supermarket lighting including long operating life, lower maintenance costs, reduced radiated heat, minimal light loss, dimmability and controllability, direction illumination, and adjustable color when compared to traditional sources.[1] At this time, however, the initial cost of LED linear light bar system in general is much higher than alternative light sources such as T8 fluorescent lamps.

Information from the US Department of Energy suggests LED technology is changing at a rapid pace such that, "since 2002, commercial white LED device efficacies have increased from 30 L/W (DOE, 2006a) to about 100 L/W in 2008."[2] Due to these rapid advances in this field, it is expected that even more robust LED products will be entering the market which may make this direct one-for-one replacement scenario a viable solution by meeting a broader base of customer investment criteria.

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

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

MARKET OVERVIEW

The penetration of LEDs into the retail supermarket lighting display niche is of importance for energy efficiency measures because this application normally involves long hours of operation and is potentially one of the better applications in which LEDs are currently considered a viable and customer accepted solution. Currently, the market penetration of LEDs in the retail supermarket refrigerated/freezer case application is estimated at 3.6% according to the 2008 DOE SSL Niche Market Final Report. [3]

A US DOE sponsored report prepared by Navigant Consulting Inc. (NCI) in 2002 estimates that lighting makes up approximately 22% of IOU kWh sales on a national scale. Using kWh sales figures from a 2006 study, the total consumption in SDG&E®'s service territory for lighting is calculated to be on the order of 4,093 GWh in 2002.[4] This study also provides values for kWh lighting figures within SDG&E®'s commercial sector only. A 2002 DOE study, found that of the total commercial lighting in the United States about 12% is consumed by retail display areas, with an estimated 1.8% attributed to refrigerated/freezer case lighting. This 1.8% market share would result in an estimated energy savings potential within SDG&E® service territory of refrigerated/freezer case lighting of around 73.7 GWh.[5] It is obvious from these figures that a significant potential exists for lighting related- energy savings in the refrigerated/freezer case application market.

Finally, there is a compelling reason for supermarkets to adopt energy efficiency measures in their space. On average, supermarkets in the US use around 50 kWh of electricity and 50 cubic feet of natural gas per square foot per year — an average annual energy cost of more than $4 per square foot. For an average-size (50,000 sqft) store, this equates to more than $200,000 annually in energy costs and results in 1,900 tons of CO_2 being emitted into the atmosphere — equivalent to the emissions from 360 vehicles in one year. This is according to studies conducted by the US EPA ENERGY STAR for Retail program.[6]

Refrigeration and lighting account for over 50% of total energy use in the average supermarket. The profit margins in the food retailing market are so thin, as low as 1 percent, that ENERGY STAR for Retail estimates that "one dollar in energy savings is equivalent to increasing sales by $59. Lighting retrofits can save 30 to 50 percent of lighting energy as well as 10 to 20 percent of cooling energy.[7]

The main impetus for the retail industry to adopt new energy efficiency measures is the industry focus on the bottom line given the historically low profit margins characteristic of the food retail business. The

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

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

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

[6] ENERGY STAR for Retail: www.energystar.gov?ia/business/challenge/learn_more/Supermarket.pdf

[7] ENERGY STAR – Building Manual, Chapter 13, Facility Type: Retail, January 2008.

compelling reasons for the industry to look at energy efficiency as a margin boosting strategy are as follows:

- increased sales can result from lighting retrofits that take into account energy efficiency and provide better illuminations of products.[8]
- higher profit margins will result from the direct impact of reduced energy costs on operating expenses.
- minimize risk of energy price fluctuations which can have a severe impact on low operating margins

[8] LRC 2006 Freezer Case Study FTDeltaFreezer.pdf

Project Objectives

The objectives of this demonstration project were to examine electrical, lighting, and economic performance of LED linear light bar systems as compared to T8 fluorescent lamps in the refrigerated/freezer case applications. The potential electrical demand and energy savings were measured in terms of average wattage and estimated annual kWh usage. Lighting performance was measured in terms of illuminance, luminance and CCT (in Kelvin). Finally, economic performance was calculated using simple payback for substitution in new installation or replacement scenarios, accounting for lamp life span, maintenance costs, and electrical costs.

Methodology

HOST SITE INFORMATION

The facility selected for this project was a retail supermarket store, Albertsons, in San Clemente, CA. This project focused on providing direct replacement lighting for T8 fluorescent lighting systems used in refrigerated/freezer cases.

The existing lighting system consisted of 40 W T8 fluorescent for 112 refrigerated/freezer case lamps. The customer selected LED linear light bars as the replacement lighting system. The LED system was rated at 23 W, 37 L/W and 4,100 K.

Prior to recording the data, both the existing T8 fluorescent and LED system were operated for approximately 100 hours of burn-in time.

LIGHTING TECHNOLOGY

This project involved the demonstration of LED linear light bars. The performance characteristics including CCT (K) and power (W) are listed in Table 3 below.

Table 3: Results for LED linear light bar system

Lamp	Color Temperature Description	Color Temperature (K)	Beam Spread (°)	Power (W)
LED	White	4100	120	20.8

The LED linear light bars were compared to T8 fluorescent lamps that were currently in use at Albertsons. Product information on the existing fluorescent lamps, provided by the manufacturer, is included in Table 4 below.

Table 4: Manufacturer Specifications for Existing Fluorescent Lamps

Fluorescent Manufacturer	Color Temperature Description	Color Temperature (K)	Beam Spread (°)	Company Stated Power (W)
GE Slimline F40T8-SPX35	35	3,500	-	40

Ballast Manufacturer	Description	Number of Lamps	Power Factor	Class
BC Lighting	BC 120-240LT	2	High	P
Anthony Door	Model LT2X40/120	2	High	P

MEASUREMENT PLAN

The Measurement Plan included initial, pre-installation and post-installation field visits to the Albertsons store in San Clemente. Initial field visits were made to meet with the facility staff, note the general pre-retrofit lighting conditions in the facility and to discuss the retrofit design and schedule the pre and post installation monitoring.

A pre-installation field visit occurred to observe and document the existing condition of the lighting system. This visit was scheduled to minimize inconvenience and reduce impact at the demonstration facility. In accordance with common industry practice, the visit occurred at a time when the pre-retrofit T8 fluorescent lamps in the testing areas had been in use for approximately 100 hours.

A post-installation field visit was used to document the new condition of the lighting system. This visit took place one week after the installation field visit. All photographs and lighting characteristic measurements were taken in a manner consistent with the procedure for the pre-installation visit. In addition, an informal Lighting Performance Survey was conducted with the showroom staff who had direct interaction with the LED demonstration areas to determine comparative lighting performance between pre- and post-retrofit lighting systems.

Data collection methodology was conducted as follows. A DENT Elite logger was connected to both the lighting panel and an isolated compressor circuit to monitor and collect data for conducting the power comparison and associated run times. Illuminance and luminance measurements were taken in two pre-selected freezer case doors located mid aisle to insure measurements taken under normal aisle lighting conditions in lieu of near checkout or end cap lighting. To insure similar conditions and a uniform field, a white foam board was constructed with various data points marked and placed over the actual product in two selected freezer case doors. The grid in Appendix A provides the detail layout of the data points. During this demonstration, it was discovered that one of the cases had an isolated circuit and compressor allowing for a direct reading of the impact of the lighting on the compressor load.

Monitoring equipment used in the execution of this Monitoring Plan was provided by Emerging Technologies Associates, Inc. The preferred equipment is detailed below. To ensure consistency in meter reads, ETA uses the same meters for both pre and post measurements.

Illuminance
Konica Minolta: Chroma Meter: Model CL-500

Correlated Color Temperature
Konica Minolta: Chroma Meter: Model CL-500

Power Meter
DENT ELITE pro Hi Mem, Recording Poly Phase Meter

Thermal Imaging
FlirSystems: Therma CAM T-360 Wes

Project Results

ELECTRICAL ENERGY AND DEMAND SAVINGS

The LED linear light bar system demonstrated along with the T8 fluorescent lamps operated by an electronic ballast for two lamps currently in use at Albertsons stores were tested in situ at the chain's San Clemente store to determine power consumption of each lamp used in the existing refrigerated/freezer cases.

At Albertsons, the case lighting is normally used during store hours, which are 5:00 AM to 12:00 PM, 364 days a year, resulting in an average usage of 6,916 hours per year. The measured power demand and estimated yearly energy consumption are summarized in Table 5. Table 6 displays the potential 53% demand and energy savings using the LED linear light bar system as compared to the existing 40 W T8 fluorescent lamp.

Table 5: Comparative Measured Power Demand and Estimated Energy Usage

Lamp Type	Power (W)	Est. Annual Energy Consumption (kWh)
T8 Fluorescent (40W)	44.4	307.1
LED linear light bar (20W)	20.8	143.9

Table 6: Potential Demand and Energy Savings

Lamp Type	Power (W)	Power Savings (W)	Est. Annual Energy Savings (kWh)
T8 Fluorescent (40 W)	44.4	-	-
LED linear light bar (20 W)	20.8	23.6	163.2

LIGHTING PERFORMANCE

In this demonstration, the technology under consideration is used to provide refrigerated/freezer case lighting. As a result, the primary determinant of lighting performance is quantitative measurements of illuminance, luminance and color temperature.

Customer Acceptance

A total of seven respondents participated in the survey. Overall reactions to the new LED linear light bar system from the respondents were favorable. When asked, "Do you generally prefer the new lights or the old lights?" all seven indicated preference for the new lights because the product looked "cleaner and crisper." Similarly, when asked, "Do you think the new lights will drive more or less sales?" all seven responded "An increase may occur due to better look and feel of the cases".

Illuminance

Illuminance measurements were taken using a Konica Minolta Chroma Meter (Model CL-500). Measurements were taken in product viewing areas over two refrigerated/freezer cases. The exact locations of the measurements are indicated on the diagram found in Appendix B: Case 1 Baseline T8 Fluorescent and Appendix C: Case 2 LED Linear Light Bar. Illuminance measurements were higher in most test locations for the LED linear light bar system as compared to the baseline T8 fluorescent system.

Consolidated average columnar illuminance values are shown below:

Table 7: Illuminance (average for columns of data points)

Doors 11 and 12	0 (fc)	1 (fc)	2 (fc)	3 (fc)	4 (fc)	5 (fc)	6 (fc)
T8 Fluorescent (40 W)	**158.5**	60.2	128.8	**168.7**	95.0	156.0	**156.8**
LED linear light bar (20 W)	**271.2**	138.7	91.3	**289.8**	46.8	134.8	**312.8**

Bold number denotes center mullion where light is mounted

Color

Color measurements were taken using a Konica Minolta Chroma Meter (Model CL-500). For both areas, measurements were taken in nine places, three on the left of door 11, three on the center mullion between doors 11 & 12 and three on the right of door 12. Exact location of test points can be found in Appendix A: Pre-installation Case Diagram and Post-installation Case Diagram. A summary of the correlated color temperature measurements can be found in Table 7.

The LED lamps tested in the test area had a rated CCT of 4,100 K. According to Table 8 there appears to be minimal 124 K difference in CCT between the LED linear light bar systems and the T8 fluorescent lamp system.

Table 8: Correlated Color Temperature (average for columns of data points at center mullions)

Door 11 and 12	Correlated Color Temperature (K)	
	T8 Fluorescent (40 W)	LED linear light bar (20W)
1	3,620	3,879
2	3,553	3,972
3	4,213	3,907
Average	3,795	3,919

ECONOMIC PERFORMANCE

Economic performance was evaluated primarily by simple payback calculations of the LED linear light bar system versus the T8 fluorescent lamp system. To calculate this, maintenance and energy costs were taken into account assuming current energy and materials costs.

To estimate energy cost, a 2008 SDG&E® AD rate schedule was used. This is the rate schedule used by retail businesses, under which electrical rates are varied based on time of use. For this analysis, the "'Average' Total Rate" of $0.1427 per kWh was assumed.

The electrical cost for the LED linear light bar is approximately $20.53 per year. These are compared to estimated electrical costs for the T8 fluorescent lamp system of approximately $43.81 per year. Based upon the energy savings alone the simple payback is illustrated in Table 9.

Table 9: Energy Savings Simple Payback Economics

Lamp Type	Incremental Cost ($)	Annual Savings ($)	Simple Payback (years)
T8 Fluorescent	---	---	---
LED linear light bar installed (two LED light bars per door)	276	23.28	11.9

The LED linear light bars are rated by the manufacturer at 50,000 hours. It is assumed that the LED lamps will be replaced at the end of their useful life as determined by a 30% reduction in light output from initial output. This is a reasonable assumption due to the necessity of maintaining a minimal light output in this situation, and due to the robust nature of LED technology and low risk of failure. The base case T8 fluorescent lamp systems are assumed to be replaced at the end of their rated life of 20,000 hours

For the T8 system, it is estimated that the probability of an annual ballast failure rate would be at least 10%. Additionally, the annual maintenance cost assumed that the T8 lamps would be replaced at the end of their useful life in lieu of light level degradation. Mention of light degradation is due to the fact that fluorescent sources are designed to operate optimally at indoor ambient temperatures of 60 to 80 degrees Fahrenheit. In cold temperatures, such as the -6°F of the freezer cases in this project, the light output can be adversely impacted by as much as 60%. Thus the annual maintenance cost could be considerably higher if lamps are changed on a schedule when light degradation is anticipated, perhaps annually.[9] As can be seen from Table 10, the conservative approach used to calculate annual maintenance costs for the T8 fluorescent system resulted in the LED system maintenance cost exceeding

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

the T8 fluorescent due to the high replacement cost of the LED linear light bar. This resulted in a slight increase in the number of years for the overall simple payback.

Table 10: Annual Lamp Costs (conservative approach)

Lamp Type	Annual Maintenance Cost per Lamp ($)	Annual Energy Cost per Lamp ($)	Total Annual Cost per Lamp ($)
T8 fluorescent	25.86*	43.81	69.67
LED linear light bar	32.63**	20.53	53.17

**Based upon 11 ballast changes (10%)/year total of $8.50/lamp/yr, 2.5 lamp changes over 7.2 years at a labor rate of $50.00 total of $17.36/lamp/yr*
***Estimated based upon LED linear light bar system life of 50,000 hours, 7.2 years in this case, replacement cost of $235 installed.*

Table 11: Simple Payback Economics

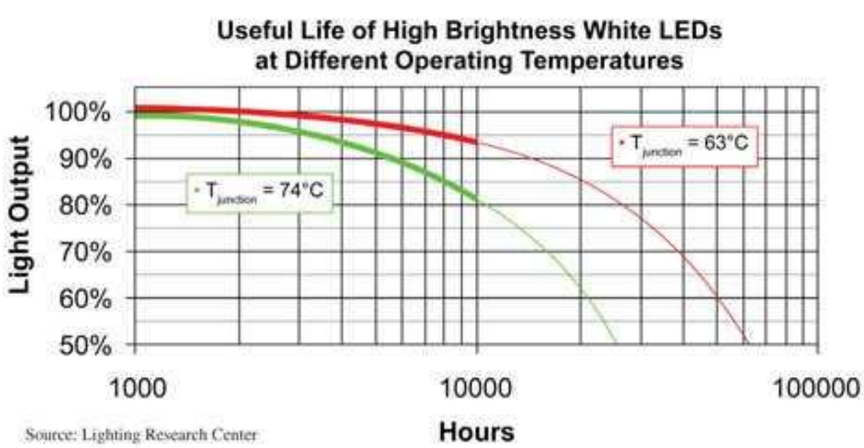
Lamp Type	Incremental Cost ($)	Annual Savings ($)	Simple Payback (years)
LED linear light bar lamp	22,400	1,848	12.1

Discussion

LED linear light bar systems have the potential for great energy savings in retail supermarket and convenience store refrigerated/freezer case lighting applications. According to a study conducted by the Lighting Research Center at Rensselaer Polytechnic Institute (RPI) titled "Refrigerated Display Case Lighting LEDs,"[10] customer preference was for product displayed in an LED illuminated case as compared to one illuminated by fluorescent sources. In the study, the fluorescent source provided more light than the LED system, at a lower input power. Although in this study, the LED system was less efficient than the fluorescent system, the LED source provided more uniform lighting. As a result, the study determined that the improved uniformity was the main reason customers preferred the LED system.

The Lighting Research Center at RPI completed a similar study for supermarket freezer cases entitled, "Energy-Efficient Lighting Alternative for Commercial Refrigeration."[11] This study concluded that shoppers preferred the LED freezer over the fluorescent freezer, even when the LED was dimmed 25% below the fluorescent freezer light level.

The Albertsons site provided an example of the achieved energy savings, with reductions in energy use of over 53% per T8 fluorescent lamp replaced. Despite the significant energy savings of the LED linear light bars system, simple paybacks were long – approximately 12 years. In the case of the host site for this project with long operating hours, Albertsons, the payback exceeds the life expectancy of the LED system. However, considering the ambient case temperature of -6 °F, it could be argued that the LED life expectancy could actually be 100,000+ hours as illustrated in the following graph (assumption is juncture temperature would be 53 °C or less).



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

[11] Narendra, Brons, Taylor, 2006.

Assuming the LED life expectancy was in fact 100,000 hours, the results of Tables 10 and 11 would be as illustrated in below.

Table 12: Annual Lamp Costs

Lamp Type	Annual Maintenance Cost per Lamp ($)	Annual Energy Cost per Lamp ($)	Total Annual Cost per Lamp ($)
T8 fluorescent	25.86	43.81	69.67
LED linear light bar	16.21*	20.53	36.74

**assumes LED life of 100,000 hours*

Table 13: Simple Payback

Lamp Type	Incremental Cost ($)	Annual Savings ($)	Simple Payback (years)
LED	22,400	3,689	6.1

As illustrated in the above tables, it is important to have the LED life expectancy be greater than the normally stated life in indoor ambient temperature conditions. Considering the temperature of the freezer case is significantly lower than indoor ambient temperatures, it could be argued that the 100,000 life is realistic as illustrated by the useful life graph developed by the Lighting Research Center shown in the previous section.

A better economic evaluation of the linear light bar system given the long useful life of LED sources is to use the life cycle costing method which would take into account the rising costs of energy assuming a 5% increase annually, the discounted value of the annual savings and factor in the high maintenance costs of the T8. A life cycle costing is beyond the scope of this report.

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

Conclusion

LED lighting has great potential for energy savings in retail supermarket and convenience store applications and the energy savings derived from new LED applications in retail spaces may exceed the performance of other energy efficient lamp types such as T8 sources. This demonstration provided an example of this potential in refrigerated/freezer case lighting. The extreme low temperatures of freezer cases have been problematic for T8 lamps. This demonstration clearly shows the LED will be a viable alternative and perhaps even capture higher energy savings when compared to existing lamps installed in freezer cases.

This demonstration did not show an acceptable payback based upon the stated 50,000 hour life expectancy of the LED and due the fact that LED’s are being compared with T-8 already in place. However, the results in this demonstration should be used to meet the needs of the retail supermarket and convenience store sphere for an energy-efficient replacement for the current lamps technology. Also, it should be noted that all results were calculated very conservatively and even greater energy savings may be realized if either the fluorescent lamps were replaced more regularly due to light degradation or if theoretical life expectancy of 100,000 hours for the LED became acceptable. The potential for savings will be substantial in SDG& E service territory if all supermarkets were to convert to LED linear bars. In order for this to occur, two key steps must be taken:

1) Further Research & Development (R&D) work must be completed by nationally recognized laboratories such as PNNL and LRC to help the manufacturers with limited R&D capital to develop a more cost effective LED linear bar and further bring the costs down.
2) The outcome of this assessment project indicates the need for “substantial” incentives to accelerate the market acceptance of LEDs for the refrigerated/freezer case lighting application. Based upon the simple payback period being greater than the life expectancy of the LED when using 50,000 hour life, the utility companies would need to consider high incentive levels up to 50% of installed cost. And this may not be so far-fetched when the utility system wide energy savings are taken into consideration. In the case of SDG&E® service territory, achieving a moderate market acceptance and adoption rate of 30% would mean saving 22.1 GWh.

As the technology increases in performance, utility or government incentive programs can help to tip the scale towards greater adoption of LED lamps by reducing the initial investment required that is the only barrier to entry for the manufacturers. SDG&E® in collaboration with other California utilities should invest in higher levels of incentives to back the market penetration of this new LED application in the first three to five years given the importance of this sector and the energy intensity of the food retail sector. This will help open up the retail market for LED technology where market acceptance is already high but the main barrier of entry is the high initial costs. These utility incentive programs should require minimum performance standards based on the new US DOE studies for qualifying products in order to ensure long-term energy savings.

Appendix A

Measurement Diagrams and Data

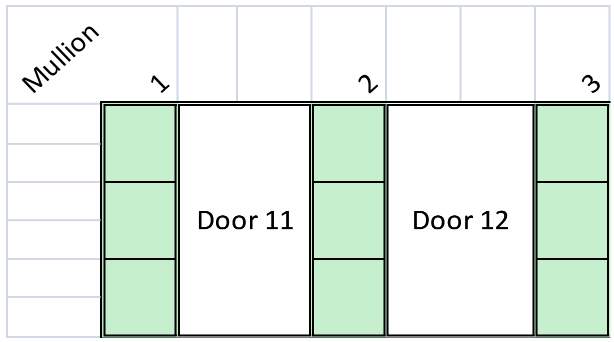


Figure A1.1: CCT data sampling configuration

Each door measures 65” x 30”

Data units: Kelvin (K)

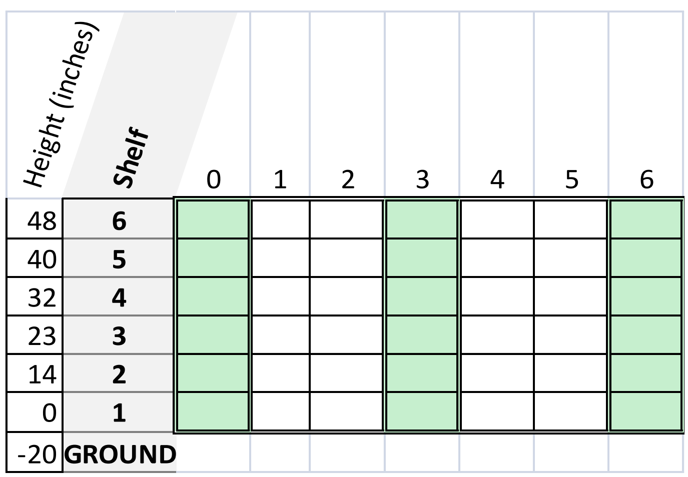


Figure A1.2: Illuminance data sampling configuration

Data unit: foot candle (fc)

Center to center data sampling points measured 12” apart for columns

Green cells represent mullions of cases and the groups of white cells represent doors 11 & 12 respectively

Appendix B

Pre-installation Data

Appendix B1: Pre-installation Data: Illumination

Height (inches)	Shelf	0	1	2	3	4	5	6
48	**6**	171	57	102	152	94	166	121
40	**5**	181	64	87	182	109	175	156
32	**4**	148	72	156	169	107	171	171
23	**3**	148	65	157	182	94	160	162
14	**2**	151	57	177	155	85	144	177
0	**1**	152	46	94	172	81	120	154
-20	**GROUND**							

Figure B1.1: Illuminance data sampling Freezer door 11 and 12

Data acquired: 10/19/08

Data unit: foot candle (fc)

Appendix B2: Pre-installation Data: Color

Mullion 1		Mullion 2		Mullion 3
3610	Door 11	3460	Door 12	4040
3640		3720		4360
3610		3480		4240

Figure B1.2: CCT data sampling Freezer door 11 and 12

Data acquired: 10/19/08

Data unit: Kelvin (K)

Appendix C

Post-installation Data

Appendix C1: Post-installation Data: Illumination

Height (inches)	Shelf	0	1	2	3	4	5	6
48	**6**	237	100	72	273	58	123	314
40	**5**	293	116	82	321	48	125	325
32	**4**	300	153	91	330	45	108	305
23	**3**	277	180	110	298	43	177	338
14	**2**	263	177	104	261	41	169	312
0	**1**	257	106	89	256	46	107	283
-20	**GROUND**							

Figure C1.1: Illuminance data sampling Freezer door 11 and 12

Data acquired: 11/3/08

Data unit: foot candle (fc)

Appendix C2: Post-installation Data: Color

Mullion	1		2		3
	3916		4013		4000
	3819	Door 11	3964	Door 12	3863
	3903		3940		3857

Figure C1.2: CCT data sampling Freezer door 11 and 12

Data acquired: 10/19/08

Data unit: Kelvin (K)