**Work Paper PGECOLTG174**

**LED Refrigeration Case Lighting**

**Revision 2**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**LED Refrigeration Case Lighting**

**Measure Codes LB03, LB05, LB07, LB09, LB11, LB13, LC01, LC03, LC05, LC07, LC09, LC11, LC13, LC15**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LB03, LB05, LB07, LB09, LB11, LB13, LC01, LC03, LC05, LC07, LC09, LC11, LC13, LC15 |
| **Measure Description:** | LED light bars replacing single or multiple lamp fluorescent profiles in refrigerated display cases; without occupancy sensors; Tiers 1 through 4 |
| **Energy Impact Common Units:** | Per linear foot |
| **Base Case Description:** | Linear fluorescent lighting in refrigerated cases: <=5 foot T8 Normal Output; or > 5 foot T12 High Output |
| **Base Case Energy Consumption:** | Various, per existing lamp configuration and per linear foot  Source: PG&E calculations |
| **Measure Energy Consumption:**  Source: PG&E calculations | Various, per-linear foot and controls  Source: PG&E calculations |
| **Energy Savings (Base Case – Measure)** | Various, per existing lamp configuration, per-linear foot and controls  Source: PG&E calculations, 2011 hours of operation and IE effects |
| **Costs Common Units:** | $ per unit |
| **Base Case Equipment Cost ($/unit):** | Various, per linear foot  Source: PG&E calculations |
| **Measure Equipment Cost ($/unit):** | Various, per-linear foot  Source: PG&E calculations |
| **Measure Incremental Cost ($/unit):** | Various, per-linear foot  Source: PG&E calculations |
| **Effective Useful Life (years):** | Varies by building type  Source: 2011 DEER |
| **Program Type:** | Replace on burnout (ROB) / Direct Install (DI) |
| **Net-to-Gross Ratios:** | 0.6,  Source: 2014 DEER, NTGR\_ID= All-Default>2yrs |
| **Important Comments:** | Revised savings values per ED Workpaper Disposition for Lighting Retrofits, December 14, 2013. For updated savings values, see file PGECOLTG174 R2. Removed measures with occupancy sensor savings to accommodate 2013 Title 24. |

# Document Revision History

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| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section by Section Description of Revisions** | **Author (Company)** |
| Revision 0 | 06/08/2012 | Original work paper | Greg Barker and Joey Lande (Energy Solutions), reviewed by Jim Wyatt and Alina Zohrabian |
| Revision 0 | 8/29/12 | The “Com” building type is the weighted up value from DEER building types. OTR explanation is added in the workpaper. For Vintage AV is changed to EX and For Climate Zone All is changed to IOU | Alina Zohrabian (PG&E) |
| Revision 1 | 5/19/2014 | Updated for 2013 T24 update by removing measures with occupancy sensors. Revised savings values per ED workpaper Disposition for Lighting Retrofits, December 2014, 2013. | Mark Tiemens (PG&E) |
| Revision 2 | 1/1/2016 | Updated hours of operation, EUL per DEER2016 | Linda Wan (PG&E)  Tai Voong (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description***

Light emitting diodes (LEDs) are emerging as a viable replacement for incandescent and fluorescent lighting technologies in certain applications. One such application is refrigerated cases for perishable goods. Refrigerated cases are found in most grocery stores and convenience stores, as well as some other specialty stores. Illumination in refrigerated cases is typically provided by fluorescent sources, but while fluorescent light sources are efficient, they are optimized to operate in ambient air temperatures of 60ºF to 80ºF.

Performance of LED light sources improves in cold temperature applications. Many of the LED components available specify that they are suitable for use in low temperature settings. The brightness, long life and high efficacy of LEDs make them a suitable energy efficient replacement for fluorescent lighting in refrigerated cases. Demonstration projects have shown that customer response to LED case lighting is positive, and even when there has been a reduction in light levels with new case LEDs, store staff have viewed the lighting technology change favorably[[1]](#endnote-1). There are also indications that refrigerated case LEDs may have a positive impact on product sales.[[2]](#endnote-2) LEDs save energy, perform well in the cold environment and provide consistent luminance.[[3]](#endnote-3) The energy savings results from reduced lighting load and reduced refrigeration load due to reduced heat gain from the lighting equipment.

This work paper details the energy and demand savings of new measures related to LED lighting in refrigerated cases.

Table Measure Codes and Descriptions

| **Code** | **Description** |
| --- | --- |
| LB03 | Linear foot of Tier 1 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LB05 | Linear foot of Tier 1 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LB07 | Linear foot of Tier 2 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LB09 | Linear foot of Tier 2 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LB11 | Linear foot of Tier 3 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LB13 | Linear foot of Tier 3 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing single lamp profile |
| LC01 | Linear foot of Tier 1 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC03 | Linear foot of Tier 1 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC05 | Linear foot of Tier 2 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC07 | Linear foot of Tier 2 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC09 | Linear foot of Tier 3 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC11 | Linear foot of Tier 3 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC13 | Linear foot of Tier 4 LED Lightbar, <= 5-foot unit, no occupancy sensor control replacing multiple lamp profile |
| LC15 | Linear foot of Tier 4 LED Lightbar, > 5-foot unit, no occupancy sensor control replacing multiple lamp profile |

The twenty eight new measures (4 tiers) are designed to offer customers with additional opportunities to reduce lighting and refrigeration costs. Customers can choose the appropriate wattage and light output for the LED case lighting to replace their linear fluorescent lamps. Additional savings opportunity is available to customers who further reduce kWh usage with occupancy sensors, or with the removal of multiple lamp profiles.

The wattage limits of the tiers are designed to incentivize the sale of the most efficacious lightbars available, while also considering that certain applications require a higher wattage lightbar to provide adequate light levels.

Table Product Descriptions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Product Description** | **Wattage** | **Basecase lamp length** | **Occupancy Control** | **Basecase lamp profile** |
| Linear Foot of Tier 1 LED Lightbar | <=2 watts/foot | <=5 or >5 foot lamp | without occupancy sensor | Replacing single or multiple lamp profile |
| Linear foot of Tier 2 LED Lightbar | >2 watts/foot <=4 watts/foot | <=5 or >5 foot lamp | without occupancy sensor | Replacing single or multiple lamp profile |
| Linear foot of Tier 3 LED Lightbar | >4 watts/foot <=6 watts/foot | <=5 or >5 foot lamp | without occupancy sensor | Replacing single or multiple lamp profile |
| Linear foot of Tier 4 LED Lightbar | >6 watts/foot <=9 watts/foot | <=5 or >5 foot lamp | without occupancy sensor | Replacing multiple lamp profile |

Within each tier there is an option for claiming credit for lamp removal, for refrigerated cases where fluorescent lamps currently exist side-by-side, referred to here as multiple lamp profile. The fourth tier, for highest-wattage LED lightbars, applies to the highest output horizontal lightbars, which are installed as a replacement for multiple lamp, high output canopy fixtures. This tier of LED lightbar only qualifies for incentives when replacing multiple lamp profile fluorescents, as a single lamp profile basecase would provide little or no savings. This tier gives customers an option to replace multiple fluorescent lamps with a single lightbar, while qualifying for a higher incentive and increasing energy savings.

An analysis of PG&E- and Design Lights Consortium (DLC)-qualified LED products was conducted to survey the distribution of lightbars across different wattage ranges. PG&E will continue to use the DLC listing requirements for luminous efficacy (lm/W) and light distribution for these products. Determination of which of the 4 tiers, if any, a DLC-listed product qualifies for will be based on the wattage of the product. The wattage requirement for the highest savings tier, Tier 1, is restrictive enough to mean that most products at the writing of this workpaper will not qualify, and this was done intentionally to prolong the useful life of these measures before new savings assumptions are needed, given the improvement trends in LED light output and efficacy.

A special methodology applies to the calculation of qualifying per-foot wattage for a vertical lightbar. This allows manufacturers to claim center-mounted and end-mounted lightbars as part of the same measure code. Most manufacturers produce a center lightbar that illuminates in two directions from a center mullion and an end lightbar that illuminates only one direction, to replace the fluorescent lamp mounted up against the side of a refrigerated case. These two products are typically sold as part of the same product family. A few manufacturers install identical units for centers and ends. Rather than assign products in the same family to different tiers, the center/end lightbar combination will be qualified for a specific tier based on the average of their wattages weighted by the relative prevalence of center and end units. The prevalence data is taken from more than 3 years of historical data from PG&E’s ERCO program, and it was determined that there are on average 2.19 center bars for every end bar; in other words the average case has two end bars and 4.38 center bars. The qualification wattage of a vertical lightbar combination will be calculated with this formula:

**Qualifying Wattage/foot = [(Center Bar Watts/foot) x 2.19 + (End Bar Watts/foot)] / (1 + 2.19)**

**Definitions:**

Refrigerated display cases come in a variety of shapes and sizes. This work paper is designed to include all LED refrigerated case lightbars regardless of the orientation of the lighting product and whether the case is open or closed.

Vertical Reach-In Display Cases: “Vertical Cases” cases are either low-temp (i.e. freezers) or medium temp (i.e. refrigerators) and generally hold frozen and other perishable food products. Some reach-in cases are also “walk-in” for stocking purposes, but still have a vertical door closed door facing the customer. The lights illuminating the food products are found on the bars separating two doors, called mullions, and at each end of a set of doors.

Horizontal, Open Case: “Horizontal Cases” are commonly referred to as “multi-deck” cases and are often found in grocery stores to display meats, dairy products, beverages, produce and baked goods. The lights illuminating the food products are found in three basic places:

1. “Canopy” lights are down-lights located at the top of the case that can potentially illuminate all levels of a multi-deck case
2. “Shelf” lights are found under multi-level shelves
3. “Nose” lights, also referred to as “rail” lights, are up-lights located at the bottom of the case closest to the consumer

***Program Restrictions and Guidelines***

This program is for replace on burnout, for non-residential customers. The delivery channel for these measures will be Midstream/Upstream Programs. This measure is also available for direct install applications. This program has no climate zone or building restrictions.

Horizontal and Vertical Case Lighting must be on the DesignLights Consortium qualified product list and be listed with the Department of Energy Lighting Facts Program. The DLC specifications for horizontal and vertical refrigerated case lighting are shown here[[4]](#endnote-4):

Table Technical Requirements for Display Case Luminaires from DLC

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **General Application** | **Requirements** | | | | | | |
| **Minimum Light Output** | **DLC Standard** | | | **DLC Premium** | | |
| **Minimum Efficacy (lm/W)** | **Minimum Warranty (years)** | **CCT/CRI/L70** | **Minimum Efficacy (lm/W)** | **Minimum Warranty (years)** | **CCT/CRI/ L90/ L70** |
| Display Case | 50-375 lm/ft | 50 | 5 | ≤ 5000 / ≥ 80 / ≥ 50,000 | 85 | 5 | ≤ 5000 / ≥ 80 / >36,000 / ≥ 50,000 |

Table Light Output and Zonal Lumen Distribution from DLC

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Primary Use Designation** | **Minimum Light Output (lm)** | **Zone/Space Criteria** | **ZLD/SC Nominal Requirement** | **ZLD/SC Tolerance** | **ZLS/SC Requirement with Tolerance** |
| **Vertical Refrigerated Case Luminaires-center\*\*** | 100 lm/ft | 10-90º | ≥95% | -3% | ≥92% |
| **Vertical Refrigerated Case Luminaires-end\*\*\*** | 50 lm/ft | 10-90º | ≥95% | -5% | ≥90% |
| **Horizontal Refrigerated Case Luminaires** | 100 lm/ft | 0-90º | ≥95% | -3% | ≥92% |

***Terms and Conditions:***

The customer must be a non-residential PG&E electric customer. Incentives are available in two channels: for the Midstream / Upstream channel products must be sold by a Qualified Participant; for the 3rd Party channel these measures could be delivered by a direct install program. All participants must sign a participation agreement and must be pre-enrolled prior to applying for incentives.

Horizontal and Vertical Case Lighting must be on the DesignLights Consortium qualified product list and be listed with the Department of Energy Lighting Facts Program.

LED lightbar savings are based on the replacement of existing single or multiple lamp fluorescent with a new LED lightbar, with a wattage below the maximum value of one of four tiers.

Measure lengths are in whole feet only, and actual LED lightbar lengths are often slightly shorter than the length of fluorescent lamp being replaced. The measure quantity, in linear feet, is determined by the original fluorescent lamp length, and the LED lightbar may be as much as 2 inches longer or 10 inches shorter than the original fluorescent lamp.

These rebates cannot be combined with rebates from other catalog measures or other programs claiming lighting savings.

***Market Applicability:***

These measures are primarily applicable to the grocery store sector, provided that the customer meets the terms and conditions above. In some cases, these measures may also be applicable to the small business, retail, hospitality, and hospital sectors that have lighted refrigerated cases.

***Type of Transaction:***

This measure is applicable in replace on burnout (ROB) transactions in Upstream/Midstream channels, and in direct install (DI) transactions in 3rd Party channels. The rebate incentivizes the choice of lower-wattage fluorescent equipment over the base case industry standard equipment.

***1.2 Product Technical Description***

The measure case products are LEDs arranged in a linear, narrow “lightbar” that are installed in a vertical or horizontal refrigerated case and classified by wattage as Tier 1, Tier 2, Tier 3 or Tier 4. The unit for these measures is “linear foot.” A distinction is drawn between LED fixtures 5 feet and less and longer than 5 feet due to a difference in base case lamp types; T8 and T12HO respectively. A linear foot of LED will replace a linear foot of fluorescent lighting, in a single or multiple lamp profile.

The base case products for these measures are fluorescent lamps and ballasts. Surveys of grocery stores and correspondence with vendors and manufacturers has shown that there are very few, if any, T8 lamps installed in refrigerated cases that are longer than 5 feet. Conversely, market surveys have shown that lamps 5 feet and shorter are predominantly T8. For the energy savings and cost calculations in this workpaper, all 6 foot lamps are assumed to be T12HO, and all lamps 5 feet and shorter are assumed to be T8.

## 1.3 Measure Application Type

The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata\_format-V0.97.xls*, defines the terms as follows:

Table 5 Measure Application Type[[5]](#endnote-5)

Identifies the measure application type in the Measure Implemenation table in DEER2016.

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| *ER* | *Early retirement* | *measure applied while existing equipment still viable, or retrofit of existing equipment* |
| *ROB* | *Replace on Burnout* | *measure applied when existing equipment fails or maintenance requires replacement* |
|  |  |  |

All the measures within this workpaper are ROB.

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

The Database for Energy Efficiency Resources (DEER) provides California energy savings for many technologies. These measures are not found in DEER and therefore, DEER difference analysis is not applicable.

**Therms Savings Assumption (ΔTh)**

Gas Savings **(ΔTh): The Interactive Effects are from DEER 2016**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Interactive Only?** | **Gas Savings Therms** | **DEER units** | **DEER Version** | **Impact IDs** |
| Varies – all Non-Res types | AV | All | Yes | Varies | Therms/kWh | 2011 v4.01 | N/A |

**Hours of Operation**

Annual hours of operation are based on the “GRO” building type hours of 4,710 from DEER 2016.

**Net-to-Gross**

The table below summarizes all applicable Net-to-Gross ratios for programs that may be used by these measures, based on the DEER READI tool.

Table 6 Net-to-Gross Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR value was obtained using the DEER READI tool. The relevant IR value for the measures in this work paper is listed in the table below:

Table Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective Useful Life**

EUL varies across building types based on the different hours of operation. READI tool has an EUL of 16 years for Display case Lighting LED’s. (EUL\_ID= GrocDisp-FixtLtg-LED). Since READI tool shows an EUL of 16 years for this grocery measure, the LED lifetime in hours is calculated as 16 times the GRO annual operating hours, 16\*4710 = 75,360 hours. This value is used to calculate the EUL for the different building types.

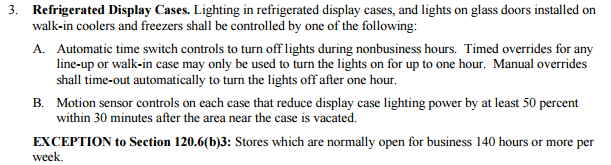
Table Effective Useful Life

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| GrocDisp-FixtLtg-LED | Display Case Lighting LED Lighting | Com | Lighting | 16 | 5.3 |

## 1.4.2 Codes & Standards Requirements Base Case and Measure Information

***Title 20:*** These measures do not fall under Title 20 [2015] of the California Energy Regulations, however, maximum annual energy consumptions outlined in Section 1605.1(a), 1605.2(a), and 1605.3(a) for commercial refrigeration should also include the energy being used for lighting and illumination.

***Title 24:*** Controls for refrigerated display cases are mandatory in Title 24 [2013] in Section 120.6(b)3. The following is an excerpt from Section 120.6(b)3 relevant to the measures in this work paper.



***Federal Standards:*** The Energy Policy Act of 2005 (EPAct 2005) required the Department of Energy to develop energy efficiency standards for many types of commercial refrigeration equipment, including display cases. However, the regulatory language does not cover specific technologies, but rather energy performance of the display case as a whole. In addition, EPAct 2005 covers “General Service” fluorescent lamps (GSFLs), and a GSFL standard takes effect July 2012, but non-general applications are excluded. Fluorescent lamps specifically designed for cold temperature installations are specifically excluded from regulation.[[6]](#endnote-6)

## 1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

LED Refrigerated Case lighting technology has been closely tracked in California Emerging Technology studies. PG&E has conducted a series of three ET studies, and SCE and SMUD have conducted studies: Application Assessment Reports #0723[[7]](#endnote-7), #0722[[8]](#endnote-8), #0608 (Ref #3)and #0606 (Ref # 5). These studies have all studied reach-in cases (i.e. with glass doors), and all but one have focused on low-temperature rather than medium-temperature cases (i.e. freezers instead of refrigerators). Even with these limitations, the ET studies provide reliable information on lighting performance, the contribution of refrigeration savings and occupancy sensing savings, and customer satisfaction.

PG&E’s Emerging Technologies group has established that nearly half of supermarket electric costs are spent on refrigeration, and that lighting accounts for about 15% of the total energy consumed by commercial refrigerators. The ET group’s demonstration projects show that LED refrigerated case lighting can lower lighting energy usage, and produce refrigeration savings as well.

Another gauge of the market potential in LED refrigerated case lighting is the continuing success of the PG&E’s ERCO midstream program, and the vendor and customer feedback in day-to-day Program operations. To date, the PG&E offerings for refrigerated case LED lighting have focused entirely on vertical cases. Vendors and customers have relayed that while vertical cases are a good application, additional potential can be found in horizontal case lighting, where multiple lamp profiles are common, particularly for canopy lighting. Current ERCO participants indicate support for the expanded measures in this workpaper.

LED lighting is a rapidly advancing technology. It is anticipated that on-going improvements to LED technology, power supplies, and installation methods will lead to continuing price reductions and increases in energy savings.

## 1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

**Energy Savings Assumption (ΔW):**

* Base case wattages shown below are based on averages from the PG&E 2013-2014 Appendix B Table of Standard Lighting Wattages.[[9]](#endnote-9) All lightbars 5 feet and shorter are calculated with a base case of T8 lamps and normal ballast factor, standard efficiency ballasts. 6 foot fixtures are calculated with a base case of T12 lamps. Base case wattages are an average of Appendix B listings for T12HO lamp/ballast combinations for that length.
* Measure case wattages are based on the maximum allowable per-foot wattages for Tiers 1 through 4. Wattages for product qualification are taken from the Design Lights Consortium lists. Measure lengths are in whole feet only, and actual LED lightbar lengths are often slightly shorter than the length of fluorescent lamp being replaced. The measure quantity, in linear feet, is determined by the original fluorescent lamp length, and the LED lightbar may be as much as 2 inches longer or 10 inches shorter than the original fluorescent lamp.
* The methodology for calculating the annual electrical energy savings from both lighting and refrigeration, in kWh/year, is explained in section 2.1.
* SCE’s emerging technology demonstration showed that with occupancy sensing in aisles with refrigerated display case lights, measured demand reduction is generally only 5-10% during peak periods as a result of high customer traffic. Therefore, no additional peak demand reduction is claimed for this measure.
* Because Grocery (GRO) is the dominant building type for these measures, the default Com building type will use the Operating hours and interactive effects assumptions from the GRO building type. Any Upstream savings calculated using the Com default building type will be based on GRO operating hours.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Electric Savings Watts** | **Savings units** | **Reference** |
| Varies – all Non-Res types | AV | All | Varies | Watts | Appendix B, Manufacturer & Vendor Data, ET Case Studies and PG&E calculations |

**Base Case Costs and Measure Case Costs:**

* Estimated fixture costs are based on an extensive survey of vendors from 2011. While the costs shown incorporate the best information available, vendors described significant differences in mark-up practices. It can be assumed that equipment costs may vary greatly, influenced by the sales channel and the manufacturer.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **Costs ($)** | | |  |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **Base Case** | **Measure Case** | **IMC** | **Reference** |
| Varies – all Non-Res types | AV | All | Varies | Varies | Varies | PG&E calculations |

# Section 2. Calculation Methods

### 2.0.1 Compressor Savings

Any heat contributed by lighting to a refrigerated case must be removed to maintain desired temperatures. Removing fluorescent lamps in favor of more efficient LEDs will reduce the heat load in the case, and thus reduce energy consumption by the difference in lighting fixture wattage plus an additional refrigeration factor.

The three PG&E ET studies have established several assumptions for calculating the refrigeration savings:

1. Most, but not all, of the electrical energy from case lighting is dissipated inside the case. Generally the fluorescent ballast or LED power supply is outside the refrigerated compartment and does not contribute heat to the case. The percentage of lighting energy introduced to the case varies between 86% and 90% of the lighting wattage. The exact percentage used in each study varies by the precise model number and nominal wattage of each luminaire, so this assumption is presented as an average rather than calculated for each specific product.
2. Most, but not all, of the electrical energy introduced into the refrigerated case is dissipated as heat (rather than light) energy. Based on data from the Handbook of the Illuminating Engineering Society, 79% of the electrical energy is dissipated as heat.
3. Less than 1 Watt of energy is required to remove 1 Watt of heat from the refrigerated case by running the refrigerant compressor motor. This relationship is expressed as the compressor coefficient of performance (COP). COPs for refrigerated cases in the ET studies vary between 1.4 (for freezers) and 2.5 (for refrigerators).

Refrigeration energy consumption can be calculated by combining these three assumptions:

Refrigeration Energy = Lighting Energy x % Lighting inside case x % lighting as heat / COP

This equation can be rewritten to express refrigeration energy as a percentage of lighting energy

% Refrigeration Energy = % Lighting inside case x % lighting as heat / Compressor COP

Using typical numbers from the ET studies yields the following:

% Refrigeration Energy = 90% x 79% / 1.9 = 37.4%

Total Energy = Lighting Energy x 137.4%

Similar assumptions are used for Refrigeration savings in all three ET reports. For this workpaper, the assumptions from each ET report were weighted to account for the correct proportion of medium-temperature and low-temperature cases. For each measure in this workpaper, refrigeration wattage is calculated as an additional 37.4% of the case lighting wattage, representing an average of the ET study results weighted by case temperature.

## 2.1 Electric Energy Savings Estimation Methodologies

* This measure includes HVAC interactive effects savings.
* This measure is not an Early Retirement measure.

Field surveys and feedback solicited from vendors has shown that horizontal refrigerated cases are often equipped with fixtures that have a multiple lamp profile, particularly in the canopy area of the fixture. Shelf and nose fixtures normally use a single lamp profile, though multiple-lamp profile configurations do exist in nose lighting. Vertical refrigerated cases are normally illuminated with fluorescent fixtures using a single lamp profile. While fixtures 5 feet and shorter use both T12 and T8 lamps and ballasts, 6 foot fixtures overwhelmingly use T12HO equipment—no other lamp types have been documented.

The light output of the measure case fixtures will be typically lower than the overall light output of the base case fixtures, but typically offer improvements in distribution and uniformity. Measure case light output will also vary based on the lamp profile of the existing fluorescent fixture. In instances of a multiple lamp profile fixture, vendors may install multiple LED lightbars in an attempt to match the output of the existing fixture. One alternative is to install a single LED lightbar as a replacement for a multiple lamp base case. This is commonly referred to as “de-lamping”, although somewhat inaccurately in technical terms because the lighting technology type has changed, and the LED product is not technically a lamp.

When de-lamping occurs, the vendor may install a higher wattage, higher output lightbar than used for single-lamp replacement. Therefore the fourth, highest-wattage tier of LED lightbars is only applicable in cases of de-lamping. Products from Tiers 1 through 3 may be used in conjunction with de-lamping if customers’ needs for illumination are met.

**∆Watts/linear foot:** The demand difference (watts per linear foot) is the difference between the electric demand of the base fixture in watts/foot and the electric demand of the energy efficient fixture in watts/foot, all multiplied by the compressor savings factor of 137.4%.

**∆Watts/foot = (Base Case Watts/foot - Measure Case Watts/foot) x Compressor Savings Factor**

**Where:**

**Base Case watts/foot varies between 7.6 W and 36.3 W, representing the watts per foot of a fluorescent system that is either T8 or T12, and either single-lamp profile or multiple-lamp profile. For this workpaper, every multiple lamp profile configuration is treated conservatively as 2-lamp profile, even though field surveys have shown that 3-lamp profile system do exist.**

**Measure Case watts/foot is the maximum wattage that defines the appropriate tier—either 2 W, 4 W, 6 W or 9 W—increased by the 37.4% refrigeration savings factor. The examples below are for a Tier 3 LED.**

**Examples:**

**∆Watts/foot = (7.6 W – 6 W) x 137.4% = 2.2 ∆Watts/foot**

**∆Watts/foot (multiple lamp profile)= ((2 lamps x 7.6 W) – 6 W) x 137.4% = 20.9 ∆Watts/foot**

**Annual Electric Savings:**

**Annual Electric Savings= ((∆Watts/foot) x (DEER 2011 Energy Interactive Effects) x (DEER 2011 Annual Hours of Operation)/ (1,000 Watts / kW)**

**Example for GRO building type:**

**Annual Electric Savings = ((2.2 ∆Watts/foot x (0.93) x (4,910 Annual Hours of Operation) / 1000 Watts/kW) = 10.0kWh**

**For the Upstream/Midstream program instead of the “Com” building type hours of operation and interactive effects the “GRO” building type hours of operation and interactive effects are used since for this measure “GRO” is the most common building type.**

## 2.2. Demand Reduction Estimation Methodologies

* This measure includes HVAC interactive effects savings.
* This measure is not an Early Retirement measure.

**∆Watts/foot:** The demand difference (watts per foot) is simply the difference between the base fixture’s watts/foot and the electric demand of the energy efficient fixture in watts/foot, all multiplied by the compressor savings factor of 137.4%.

**∆Watts/foot = (Base Case Watts/foot - Measure Case Watts/foot) x Compressor Savings Factor**

**Where:**

**Base Case watts/foot varies between 7.6 W and 36.3 W, representing the watts per foot of a fluorescent system that is either T8 or T12, and either single-lamp profile or multiple-lamp profile. For this workpaper, every multiple lamp profile configuration is treated conservatively as 2-lamp profile, even though field surveys have shown that 3-lamp profile system do exist.**

**Demand Reduction:**

**Demand Reduction [kW/foot] = (∆Watts/foot) x (DEER 2011 Lighting Coincident Demand) x (DEER 2011 Demand Interactive Effects) / (1,000 Watts/kW)**

**Example for GRO building type:**

**∆Watts/foot = (7.6 W – 6 W) x 137.4% = 2.2 ∆Watts/foot**

**Demand Reduction [kW/foot] = (2.2 ∆Watts/foot) x 0.69 x 1.27 / (1,000 Watts/kW**

**= 1.94 kW**

**For the Upstream/Midstream program instead of the “Com” building type Coincident demand factor and interactive effects the “GRO” building type Coincident demand factor and interactive effects are used since for this measure “GRO” is the most common building type.**

## 2.3. Gas Energy Savings Estimation Methodologies

There are no therm interactive effects for this measure. Therefore there is no negative therm savings associated with this measure.

# Section 3. Load Shapes

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure’s load shape. The measure’s load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure’s Total Resource Cost (TRC) benefit.

## 3.1 Base Case Load Shapes

The closest load shape chosen for this measure is the PGE:DEER:Com:Indoor\_Non-CFL\_Ltg load shape.

## 3.2 Measure Load Shapes

The measure load shape for this measure is determined based on the applicable commercial market sector and the lighting end-use.

The closest load shape chosen for this measure is the PGE:DEER:Com:Indoor\_Non-CFL\_Ltg load shape. See Table 4 for a list of all Building Types and Load Shapes.

Table 10 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| All commercial building types, “Com,” and “OTR” | PGE:DEER:Com:Indoor\_Non-CFL\_Ltg | NON\_RES |

# Section 4. Base Case & Measure Costs

Data on both base case and measure fixture costs are derived from product pricing provided by vendors via personal communications and online price listings where available. In refrigerated case lighting as in other lighting applications, new generation LEDs are more expensive than older fluorescent equipment. DEER cost data is not available for this application and has not been used in this workpaper. These measures are dominantly ROB so the cost is calculated as the incremental measure cost. The labor to replace a base case and measure case is assumed to be the same so the cost is calculated as the difference of the cost of material for the base and measure case. For the direct install the labor is added and Full measure cost is calculated instead of the incremental cost.

## 4.1 Base Case(s) Costs

The following Transaction types are appropriate to these measures. The Base Case Costs are:

|  |  |  |  |
| --- | --- | --- | --- |
| ***Measure Code*** | **Transaction** | **Baseline** | **Equipment Cost** |
| LB03, LB07, LB11 | ROB/DI | Linear Foot of T8 Fluorescent Case Lamp with ballast, single lamp profile | $3.14 |
| LB05, LB09, LB13 | ROB/DI | Linear Foot of T12HO Fluorescent Case Lamp with ballast, single lamp profile | $7.01 |
| LC01, LC05, LC09, LC13 | ROB/DI | Linear Foot of T8 Fluorescent Case Lamp with ballast, multiple lamp profile | $6.28 |
| LC03, LC07, LC11, LC15 | ROB/DI | Linear Foot of T12HO Fluorescent Case Lamp with ballast, multiple lamp profile | $14.03 |

*All costs are noted as $ per linear foot*

Base case linear foot costs are based on an extensive survey of distributors from 2010, and updated quotes provided by contractors, fixture manufacturers, and sales reps in 2012[[10]](#endnote-10).

## 4.2 Measure Case Costs

The following Transaction types are appropriate to these measures. The Measure Case Costs are:

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Code** | **Transaction** | **Measure Case** | **Measure Equipment Cost** |
| LB03, LB05, LB07, LB09, LB11, LB13 | ROB | Linear foot of LED Lightbar, no occupancy sensor control replacing single lamp profile | $24.84 |
| LC01, LC05, LC09, LC13,  LC03, LC07, LC11, LC15 | ROB | Linear foot of LED Lightbar,no occupancy sensor control replacing multiple lamp profile | $27.50 |

*All costs are noted as $ per linear foot*

Measure case linear foot costs are based on an extensive survey of distributors from 2010, and updated quotes provided by contractors, fixture manufacturers, and sales reps in 201210.

## 4.3 Incremental & Full Measure Costs

# *4.3.1 Full Measure Cost*

This is used for the direct install measures. This is calculated as the sum of the material and labor cost for the measure case. The labor hour is taken from DEER 2008, and assumed to be the same install cost for LED Lightbars as for Linear Fluorescents.[[11]](#endnote-11) The new 2016 labor cost is three minute[[12]](#endnote-12) times $72.26 per hour equals to $3.62

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Measure Code*** | **Transaction Type** | **Labor Cost** | **Measure Equipment Total Cost** | **Full Measure Cost** |
| LB02, LB04, LB06, B08, LB10, LB12 | DI | $3.62 | $28.50 | $30.92 |
| LB03, LB05, LB07, LB09, LB11, LB13 | DI | $3.62 | $24.84 | $27.26 |
| LC01, LC05, LC09, LC13 | DI | $3.62 | $31.16 | $33.58 |
| LC03, LC07, LC11, LC15 | DI | $3.62 | $27.50 | $29.92 |

# *Incremental Measure Costs*

Incremental Measure Cost is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. While IMC has a straight forward definition depending on the install type, the equation does vary.

For Upstream/Midstream measures with transaction type ROB, the Incremental Measure Cost (IMC) is represented by the equation below:

IMC = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: The measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

IMC = Measure Equipment Cost – Base Case Equipment Cost

*IMC for the first measure = $28.50 per linear foot- $3.14 per linear foot = $25.36 per linear foot*

**Summary Table for Section 4**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure ID** | **Transaction Type** | **Base Case Total Cost** | **Measure Eqpt Cost** | **Incremental Measure Cost** |
| LB03, LB07, LB11, | ROB | $3.14 | $24.84 | $21.70 |
| LB05, LB09, LB13 | ROB | $7.01 | $24.84 | $17.83 |
| LC01, LC05, LC09, LC13 | ROB | $6.28 | $31.16 | $24.88 |
| LC03, LC07, LC11, LC15 | ROB | $14.03 | $31.16 | $17.13 |

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