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LIGHTING

LED HIGH BAY OR LOW BAY

SWLG011-02

CONTENTS

MEASURE NAME

LED High or Low Bay

STATEWIDE MEASURE ID

SWLG011-02

TECHNOLOGY SUMMARY

Historically, high-bay fixtures have used high-intensity discharge (HID) lamps (e.g., metal halide and high-pressure sodium) as the predominant light source, and low-bay fixtures have traditionally used both HID and fluorescent light source. Linear fluorescent high-output systems (e.g. T5/HO or F32T8 with VHLO ballasts) became a popular energy-efficiency measure in the early 2000s for both high and low bay fixtures due to their superior lumen maintenance, lack of restrike delay, and ability to switch with occupancy sensors.

Light emitting diodes (LEDs) first entered this market circa 2009 but early-generation LED high-bay luminaires lacked the lumen output to compete in the market. LEDs have since improved significantly making them an efficient and reliable lighting technology successfully replacing many lighting sources. Nowadays improvements in LED performance makes LED technology an ideal replacement of HID and fluorescent technologies. For most low bay applications for which linear fluorescent lighting was once common, it makes the retrofit kits and TLEDs a viable low-cost retrofit alternative to fixture replacements.

The following is a short excerpt from the CALiPER Snapshot for Industrial Luminaires[1] that gives a high-level overview:

> *"Industrial" luminaires are prevalent in both the commercial and industrial sectors, providing economical ambient lighting in large, open indoor spaces such as warehouses, manufacturing facilities, and big-box retail stores. Industrial luminaires are divided into two categories: low-bay and high-bay. Typically, low-bay fixtures are used for heights up to 20 feet, whereas high-bay fixtures are used where ceilings exceed 20 feet. Given the space demands, high-lumen-output luminaires are required, with low-bay options typically emitting between 5,000 and 20,000 lumens per fixture and high-bay options emitting between 15,000 and 100,000 lumens per fixture.*

For a high bay application for which performance requires upward of 30,000 lumens (which no fluorescent lighting can deliver), TLED and retrofit kits are practically non-existent.

MEASURE CASE DESCRIPTION

The measure case is defined as an LED fixture that replaces a less efficient LED fixture. Measure case efficacy was determined as a result of a comparison of two data sources: LightingFacts 50th percentile efficacies and DesignLights Consortium (DLC) Version 4.4 Technical Standard minimum efficacies.

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[1] U.S. Department of Energy, Energy Efficiency & Renewable Energy, Building Technologies Office. 2017. "CALiPER Snapshot Industrial Luminaires." March 13.

Due to variability of products available in various lumen bins, the measure case fixture efficacy ranges from 110 to135 LPW, with an average efficacy of 124 LPW.

Measure Offerings

Statewide Measure Offering ID	Measure Offering Description
SWLG011A	LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 110 LPW and < 130 LPW
SWLG011B	LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 110 LPW and < 130 LPW
SWLG011C	LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 110 LPW and < 130 LPW
SWLG011D	LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 110 LPW and < 130 LPW
SWLG011E	LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 110 LPW and < 130 LPW
SWLG011F	LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 110 LPW and < 130 LPW
SWLG011G	LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 120 LPW and < 130 LPW
SWLG011H	LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 120 LPW and < 130 LPW
SWLG011I	LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 125 LPW and < 135 LPW
SWLG011J	LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 125 LPW and < 135 LPW
SWLG011K	LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 125 LPW and < 135 LPW
SWLG011L	LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 125 LPW and < 135 LPW
SWLG011M	LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 130 LPW
SWLG011N	LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW
SWLG011O	LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 130 LPW
SWLG011P	LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 130 LPW
SWLG011Q	LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 130 LPW
SWLG011R	LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 130 LPW
SWLG011S	LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 130 LPW
SWLG011T	LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 130 LPW
SWLG011U	LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 135 LPW
SWLG011V	LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 135 LPW
SWLG011W	LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 135 LPW
SWLG011X	LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 135 LPW

BASE CASE DESCRIPTION

The standard practice baseline for high and low bay lighting is LED technology and the base case efficacy is the 25th percentile from Lighting Facts of minimum 100 lumens per watt (lm/W).

Due to variability of products available in various lumen bins the base case fixture efficacy ranges from 96 to116 LPW, with an average efficacy of 105 LPW.

Based on the data collected by Pacific Gas & Electric (PG&E) in February 2019 and approved by the California Public Utilities Commission (CPUC) Energy Division staff, the average efficacy of TLED is set at 111 LPW.

Energy consumption is calculated based on a mixture of TLEDs and LED new luminaires. The base case percentage mix of TLEDs and LED fixtures are shown below:

Baseline Composition of TLED and LED

Statewide Measure Offering ID	% TLED	% LED Fixt.
SWLG011A to SWLG011F, SWLG011M to SWLG011R	40%	60%
SWLG011G to SWLG011I, SWLG011S to SWLG011U	20%	80%
SWLG011J to SWLG011L, SWLG011V to SWLG011X	0%	100%

The 2019 draft of the DesignLights Consortium (DLC) Solid-State Lighting (SSL) Technical Requirements V5.0[2] proposes a standard efficacy for high bay of 120 LPW. Thus, the base case average efficacy of 105 LPW is close to the DLC V5.0 proposed future efficacy.

CODE REQUIREMENTS

There are no state or federal codes applicable to this measure.

NORMALIZING UNIT

The normalizing unit is Lumen

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All measure application type, delivery type, and sector combinations established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Normal Replacement	DnDeemed	Com
Normal Replacement	DnDeemDI	Com
Normal Replacement	UpDeemed	Com
Normal Replacement	DnDeemed	Ind
Normal Replacement	DnDeemDI	Ind
Normal Replacement	UpDeemed	Ind

[2] Design Lights Consortium (DLC). 2019. *Solid-State Lighting (SSL) Technical Requirements Version 5.0. Draft 1: Conceptual Specification.* January 29. Page 11.

Eligible Products

The measure must replace a lumen equivalent lamp/fixture of higher wattage. (See Measure Case Description).

The measure must be on the DesignLights Consortium (DLC) qualified product list (QPL) (https://www.designlights.org/search/).

The LED fixture or retrofit kit must be listed in the Technical Requirements table (V4.4) by the DLC under the General Category "High Bay" and under the Primary Use Designations as follows:

- High-Bay Aisle Luminaires
- High-Bay Luminaires for Commercial and Industrial Buildings
- Low-Bay Luminaires for Commercial and Industrial Buildings
- Retrofit Kits for High-Bay Luminaires for Commercial and Industrial Buildings
- Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings

DLC Standard requirements for the high-bay and low-bay categories include:

- 50,000-hour L70 Lumen Maintenance
- ≥ 70 Color Rendering Index (CRI)
- ≥ 105 lumens/Watt (LPW)*
- ≤ 5700 Kelvin Correlated Color Temperature (CCT)
- ≥ 5,000 Lumen light output (10% tolerance)
- ≥ 30% of Lumen Output in the 20° - 50° zone (higher for Aisle Lighting)

Additional Requirements for DLC Premium above the Standard level for the high-bay and low-bay categories include:

- 36,000-hour L90 Lumen Maintenance
- ≥ 130 Lumens/Watt (LPW)*

Specific measure case efficacy requirements listed in measure offering descriptions in the Measure Case Description.

Eligible Building Types and Vintages

This measure is applicable for all existing and new commercial, retail, and industrial facilities.

Eligible Climate Zones

This measure is applicable in any California climate zones.

PROGRAM EXCLUSIONS

Fixtures listed under specialty primary uses on the DesignLights Consortium (DLC) qualified product list (QPL)do not qualify for the deemed rebate.

Horticultural installations are not eligible.

Exterior installations are not eligible.

Screw-based lamps are not eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Lighting

ELECTRIC SAVINGS (KWH)

The calculation of annual electric unit energy savings (UES) of the LED fixture is a function of the difference between the baseline and measure case fixture wattage, hours of operation, and interactive effects.

$$UES = \frac{\Delta W \times HOURS \times IE}{1{,}000\ Wh\ /\ kWh}$$

UES =	*Unit energy savings (kWh per lamp)*
ΔWatts/unit =	*(Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp)*
HOURS =	*Annual hours of use, by building type/space*
IE =	*Interactive effects, by building type/space*

The inputs to the UES calculation are explained below.

Baseline and Measure Case Wattages for LED High and Low Bay Fixtures

Measure Case Description	Baseline Mix Watts (kLm/LPW)	Measure Watts (kLm/LPW)	Delta Watts
LED High/LowBay Luminaire rated ≥110 and <130 LPW	54 - 137	45 - 121	9 - 16
LED High/LowBay Luminaire rated ≥120 and <130 LPW	166 - 201	139 - 173	27 - 28
LED High/LowBay Luminaire rated ≥125 and <135 LPW	246 - 526	212 - 466	27 - 59
LED High/LowBay Luminaire rated ≥130 LPW	54 - 201	38 - 160	16 - 41
LED High/LowBay Luminaire rated ≥135 LPW	246 - 526	197 - 432	47 - 94

Baseline Average Watts per Fixture. The baseline fixture wattage was calculated as follows:

- Fixture rated output (lumen) divided by the rated efficacy (LPW)
- TLED rated output (lumen) divided by the rated efficacy (LPW), and then multiply by the ballast luminous efficiency and the fixture efficiency
- Sum of the two values after applying the corresponding mix percentage as shown in section “Base Case Description” above.

Measure Case Average Watts per Fixture. Initial LED lumen efficacy assumptions were set by the measure code minimum requirements, starting with the lowest-efficacy measure code corresponding with the DLC Premium tier minimum efficacy. The fixture wattage corresponding to this efficacy was accomplished by dividing the lumen output by the rated efficacy in LPW.

Annual Hours of Use, by Building Type. Annual hours of operation, which varies by building type, was adopted directly from the DEER 2020 update.[3]

Interactive Effects Multiplier. Heating, ventilating and air conditioning (HVAC) interactive effects refers to the change in HVAC energy usage due to the installation of energy-savings measures that directly change electric energy use within the conditioned space of a building. Interactive effective multipliers are developed and maintained by the CPUC Energy Division and its team of consultants via building simulation techniques that incorporate results from building site surveys, field measurements, laboratory tests, and facility billing data analysis. Interactive effects multipliers for lighting measures vary by building type, vintage, climate zone, lighting type, and occupancy sensor scenario.

The interactive effects multipliers for commercial buildings were adopted from the DEER 2020 update.[4]

The table below maps each California climate zone to an IOU service area to identify the appropriate saving value for each California climate zone.

Program Administrator	Climate Zone
SCE	CZ06, CZ08, CZ09, CZ10, CZ14, CZ15, CZ16
PG&E	CZ01, CZ02, CZ03, CZ04, CZ05, CZ11, CZ12, CZ13
SDG&E	CZ07

PEAK ELECTRIC DEMAND REDUCTION (KW)

The calculation of demand reduction impacts (kW) for the LED fixture is a function of the difference between the baseline and measure case fixture wattage (ΔW), a coincident demand factor (CDF) and interactive effects.

$$Peak\ Demand\ Reduction = \frac{\Delta W \times CDF \times IE_{elec}}{1{,}000\ W/kW}$$

ΔWatts/unit =	*(Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp)*
CDF =	*Coincident demand factor*
IE_{elec} =	*Interactive effects, by building type/space*

[3] California Public Utilities Commission (CPUC), Energy Division, Ex Ante Review Team. 2018. "DEER2020-Lighting-HVAC-IE-values.xlsx" September 7.
[4] California Public Utilities Commission (CPUC), Energy Division, Ex Ante Review Team. 2018. "DEER2020-Lighting-HVAC-IE-values.xlsx" September 7.

See the Electric Savings section for a discussion of the base case and measure case average watts per fixture used to derive the ΔW and the interactive effects multiplier.

The sources for remaining input parameters for this calculation are specified below.

Coincident Demand Factor (CDF). The coincident demand factor (CDF) represents the percentage of the time that all the lights in the building are on at the same time, during the CPUC-defined peak hours. This factor is applied to the demand savings to align the savings with this peak period. This factor varies by building type and climate zone and was adopted from the DEER 2020 update.

GAS SAVINGS (THERMS)

The estimated gas savings of an LED fixture are based solely on the estimated change of gas consumption as reflected by a gas HVAC interactive effects multiplier.

$$UES = \frac{\Delta W \times HOURS \times IE_{gas}}{1{,}000\ Wh/\ kWh}$$

UES =	*Unit energy savings (therms per lamp)*
ΔWatts/unit =	*(Base Case Average Watts per lamp) – (Measure Case Average Watts per lamp)*
HOURS =	*Annual hours of use, by building type/space*
IE_{gas} *=*	*HVAC gas interactive effects, by building type/space*

See the Electric Savings section for a discussion of each parameter in the UES calculation. The sources of the input parameters for this calculation are provided below.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

As per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on equipment measures so that the EUL of the measure itself is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component."[5]

The RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to

[5] California Public Utilities Commission (CPUC). 2016. *Resolution E-4807.* December 16. Page 13.

establish more accurate values."[6] This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[7]

The RUL of the ballast is derived in two steps: 1) determine the EUL of the ballast, and 2) determine the RUL of the ballast. The EUL of the ballast is equal to the total expected lifetime operating hours divided by the average annual operating hours (effective full-load hours, EFLH) for each building type, as shown below. Insofar as average hours of operation vary by building type, the EUL of the ballast varies by building type.

$$EUL_{ballast} = \frac{(Expected\ Lifetime\ Operating\ Hours)}{(Building\ Type\ Average\ Operating\ Hours\ Per\ Year, EFLH)}$$

$$RUL_{ballast} = \frac{1}{3} \times EUL_{ballast}$$

The inputs and resultant EUL and RUL of for this measure are presented below.

Effective Useful Life and Remaining Useful Life Inputs

Parameter	Value	Source
Expected Fixture Lifetime Operating Hours	50,000	Minimum lifetime of DLC-listed products
Hours of Use	Varies by building type	California Public Utilities Commission (CPUC). 2018. "SupportTable_2020-Com-InLtg.csv." California Public Utilities Commission (CPUC). 2018. "SupportTable_2020-Res-InLtg.csv."

Fixture Lifetime Operating Hours. The rated life of the lighting products is assumed to equal the minimum lifetime hours of DLC-listed products (though DLC products average more than 56,000 hours). The minimum of the rated life for DLC-listed products 50,000 hours is adopted for this measure.

BASE CASE MATERIAL COST ($/UNIT)

The base case fixture costs were obtained from online pricing via web-scraping in 2018 as well as from the DLC QPL list.

The base case TLED costs were obtained from online pricing via web-scraping conducted in February 2019. Because TLEDs vary widely in wattage, price, and light output, the prices were normalized by light output at the midpoint of the lumen bin.

[6] California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5.* Page 32.
[7] KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure equipment costs were obtained from California distributor catalogs and online pricing via web-scraping in 2018.

BASE CASE LABOR COST ($/UNIT)

The installation labor cost was drawn directly from the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.[8]

The base case labor cost is assumed to be the same as the measure case labor cost.

MEASURE CASE LABOR COST ($/UNIT)

The installation labor cost was drawn directly from the *2010-2012 WO017 Ex Ante Measure Cost Study* conducted by Itron, Inc.[9]

The measure case labor cost is assumed to be the same as the measure case labor cost.

NET-TO-GROSS

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG ratio for this measure was stipulated by the California Public Utilities Commission (CPUC) in 2018 Phase 1 workpaper dispositions for exterior, interior high-bay and interior low-bay fixtures and the subsequent Resolution E-4952.

This NTG value is allowed for only normal replacement (NR) and new construction (NC) measure application types.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – normal replacement only	0.91	California Public Utilities Commission (CPUC), Energy Division. 2018. "2018 Disposition Update for High and Low Bay LED Fixtures Based on Resubmission of Workpaper PGECOLTG178 Revision 3 in Response to a 2017 Phase 2 Disposition." May 7. Page 3. California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. Page A-34 – A-35.

[8] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission. Table 4-6.

[9] Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report.* Prepared for the California Public Utilities Commission. Table 4-6.

GROSS SAVINGS INSTALLATION ADJUSTMENT

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method.

Gross Savings Installation Rate Adjustments

GSIA	Value	Source
GSIA -default	0.92	GSIA ID: Com-HiBay-PGE

NON-ENERGY IMPACTS

Non-energy benefits for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes
Scaled DEER measure	No
DEER Base Case	No
DEER Measure Case	No
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	No
DEER Version	2019
Reason for Deviation from DEER	DEER does not address LED savings for panel fixtures and retrofit kits
DEER Measure IDs Used	Propose new
NTG	Source: DEER2019/E-4952. The NTG of 0.91 is associated with NTG ID: NonRes-In-Ltg-LEDFixt
GSIA	Source: DEER. The GSIA of 0.92is associated with GSIA ID: *Com-HiBay-PGE*
EUL/RUL	Source: DEER2020: The value of 12 years is associated with EUL ID: ILtg-Com-LED-50000hr. RUL is defined as 1/3 of EUL.

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	04/15/2019	Randy Kwok, PG&E	Draft of consolidated text for this statewide measure is based upon: PGECOLTG178, Revision 4 (March 1, 2019) Consensus reached among Cal TF members.
	06/14/2019	Randy Kwok, PG&E	Revisions for submittal of version 01.
	10/30/2019	Randy Kwok, PG&E	To correct IMC calculation errors for delivery types DnDeemed and UpDeemed. No impact on savings and no change in revision #.
02	12/26/2019	Adan Rosillo PG&E	Updated NTG code to NonRes-In-Ltg-LEDFixt
	02/05/2020	Adan Rosillo PG&E	Updated revision number to 02
	04/28/2020	Tai Voong PG&E	Converted measure offering impacts from IOU rolled up values to individual climate zones.