**Workpaper PGECOLTG178**

**LED High-Bay and Low-Bay Fixtures**

**Revision 4**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**LED High-Bay and Low-Bay Fixtures**

**Measure Codes: LT514 – LT537**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LT514 – LT537 |
| **Measure Description:** | LED High-Bay and Low-Bay Fixtures, various wattages  Tier 1: Minimum Efficacy of 110 - 125 lumens per watt  Tier 2: Minimum Efficacy of 130 - 135 lumens per watt |
| **Energy Impact Common Units:** | Each fixture |
| **Base Case Description:** | Percentage mix of high performance Linear Fluorescent Fixtures with 2, 3, 4, 6, 8, and 10 lamps, linear LED replacement lamps (TLEDs), and new LED fixtures and kits  Source: PG&E Calculations. |
| **Base Case Energy Consumption:** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E Calculations. |
| **Measure Energy Consumption:** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E Calculations. |
| **Energy Savings**  **(Base Case – Measure):** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E Calculations. |
| **Costs Common Units:** | $ per lumen |
| **Base Case Equipment Cost ($/lumen):** | Various. Refer to attached files PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx and Copy of TLED Cost Data\_FEB2019.xlsx  Source: PG&E & SCE Program Data, online webscraping, distributor cost data |
| **Measure Equipment Cost ($/lumen):** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E & SCE Program Data , online webscraping, distributor cost data |
| **Gross Measure Cost ($/fixture)** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E & SCE Program Data, online webscraping, distributor cost data |
| **Measure Incremental Cost ($/lumen):** | Various. Refer to attached file PGECOLTG178 R4 HighLowBay Calc\_Mar2019.xlsx  Source: PG&E Calculations |
| **Effective Useful Life (years):** | 12 years, ILtg-Com-LED-50000hr  Source: DEER 2016 |
| **Program Type:** | Normal Replacement |
| **Net-to-Gross Ratios:** | NTG = 0.91 per Deer 2019  NTG ID: NonRes-In-Ltg-LEDFixt |
| **Important Comments:** | In the ED Report (Excel spreadsheet) the MAT is showing ROB because PG&E’s system is still in the process of adopting the new MATs. PG&E will revise ROB to NR at a later time when the system is ready. |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section by Section Description of Revisions** | **Author (Company)** |
| Revision 0 | 11/4/2013 | **PGECOLTG178 R0** LED High-Bay and Low-Bay Fixtures.doc  Original Workpaper | Author: Greg Barker (Energy Solutions)  Reviewer: Alina Zohrabian (PG&E) |
| Revision 1 | 5/27/14 | **PGECOLTG178 R1** LED High-Bay and Low-Bay Fixtures.doc  Added DI values from (PGE3PLTG192-R0) and Applied new hours of operation and IE factors. For updated savings values, see file PGECOLTG178 R1.xlsx | Alina Zohrabian (PG&E) |
| Revision 2 | 1/1/2016 | NC was added.  Updated NTG, EUL, IE, CDF, GSIA, and hours of operation per DEER2016. Base case and measure costs have also been updated. | Linda Wan (PG&E)/Alina Zohrabian (PG&E)/Tai Voong (PG&E)/Henry |
| Revision 3  (Not Approved) | 8/14/2017 | -Retired measures LD101 to LD113  -Updated Title 20 Ballast Efficiency minimums;  -Created new measure codes LT105 to LT120  -Included LED high bay fixtures to replace 100W & 150W MH as well as 2- and 3-lamp fluorescent fixtures; -Used Wattage range savings estimation method recommended by Navigant Study (average of LED wattage within the range is used to calculate savings)  -Updated cost | Mini Damodaran(PG&E)/ Greg Barker (Energy Solutions) |
| Revision 3  (Interim Solution) | 4/11/2018  6/27/2018 | -Baseline percentage mixes include LEDs and remove Metal Halides  -Created Tier 1 and Tier 2 Measures  -Aligns technical requirements with DLC Technical Requirements update v4.0+  -Cost is a temporary placeholder that uses IMC as a percentage of the rebate amount  As per disposition “InteriorHighAndLowBayLEDPhase2-7May2018-Final”  -Revision 3 is effective 4/1/2018  -Updated NTG to 0.91  -Updated Measure IDs and Cost IDs | Mini Damodaran(PG&E)  Linda Wan (PG&E)  Pauravi Shah (PG&E)  Greg Barker (Energy Solutions)  Mini Damodaran(PG&E) |
| Revision 4  Revision 4 | 12/31/2018  3/1/2019 | Updated cost required by Resolution E-4952 and DEER 2019. Included tubular LED lamps (TLEDs) in the base case cost and savings calculations. Converted wattage bin measure structure to lumen bin measure structure. New Measure codes LT514 – LT537. Removed New Construction MAT. Measure will be effective 4/1/2019.  Revised TLED lamp efficacy to 111 lm/W, results in TLED fixture efficacy of 85.2 lm/W.  Revised TLED cost from $0.0042/lm to $0.0036/lm. | Greg Barker (Energy Solutions)  Randy Kwok (PG&E)  Randy Kwok (PG&E) |

# Table of Contents

[At-a-Glance Summary ii](#_Toc2804894)

[Document Revision History iii](#_Toc2804895)

[Table of Contents v](#_Toc2804896)

[List of Tables vi](#_Toc2804897)

[List of Figures 6](#_Toc2804898)

[1.1 Measure Description & Background 2](#_Toc2804899)

[1.2 Technical Description 5](#_Toc2804900)

[1.3 Installation Types and Delivery Mechanisms 6](#_Toc2804901)

[1.4 Product Base Case and Measure Data 6](#_Toc2804902)

[1.4.1 DEER Data 6](#_Toc2804903)

[1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 8](#_Toc2804904)

[1.5.1 Lighting Dispositions 8](#_Toc2804905)

[1.5.2 California LED Pricing Analysis, Navigant 2018 9](#_Toc2804906)

[1.5.3 LED Workpaper Update Study, Navigant 2015 11](#_Toc2804907)

[1.5.4 LED Non-Residential Lighting Market Characterization, Navigant – In Progress 13](#_Toc2804908)

[1.5.5 TLED Baseline 13](#_Toc2804909)

[1.5.6 CALiPER Snapshot Report June 17, 2016: 16](#_Toc2804910)

[1.5.7 CALiPER Summary Report October, 2011: 17](#_Toc2804911)

[1.6 Data Quality and Future Data Needs 17](#_Toc2804912)

[1.6.1 Standard Practice Baseline Studies 17](#_Toc2804913)

[1.6.2 Inclusion of Early Retirement (ER)/Accelerated Replacement (AR) Measure Application Type 19](#_Toc2804914)

[1.6.3 Product ID Collection Process 19](#_Toc2804915)

[1.6.4 Lighting Facts LED Database 19](#_Toc2804916)

[Section 2 Calculation Methods 20](#_Toc2804917)

[2.0.1 Equivalent Levels of Service 20](#_Toc2804918)

[2.0.2 Assumptions Used in the Calculations 21](#_Toc2804919)

[2.0.3 Measure Structure 23](#_Toc2804920)

[2.1 Electric Energy Savings Estimation Methodologies 26](#_Toc2804921)

[2.2 Demand Reduction Estimation Methodologies 27](#_Toc2804922)

[2.3 Gas Energy Savings Estimation Methodologies 27](#_Toc2804923)

[Section 3 Load Shapes 28](#_Toc2804924)

[3.1 Base Case Load Shapes 28](#_Toc2804925)

[3.2 Measure Load Shapes 28](#_Toc2804926)

[Section 4 Base Case & Measure Costs 28](#_Toc2804927)

[4.1 Base Case Costs 28](#_Toc2804928)

[4.2 Measure Case Costs 29](#_Toc2804929)

[4.3 Incremental & Full Measure Costs 29](#_Toc2804930)

[4.3.1 Full Measure Cost 29](#_Toc2804931)

[Attachments 30](#_Toc2804932)

# List of Tables

[**Table 1 LED High-Bay and Low-Bay Measure Codes** 4](#_Toc2804933)

[Table 2 Measure Application Type 6](#_Toc2804934)

[Table 3 Delivery Method and Applicable Building Types 6](#_Toc2804935)

[Table 4 DEER Difference Summary 6](#_Toc2804936)

[Table 5 Net-to-Gross Ratios 7](#_Toc2804937)

[Table 6 Installation Rates 7](#_Toc2804938)

[Table 7 Effective Useful Life/Remaining Useful Life 7](#_Toc2804939)

[Table 9 Base Case Technology Percentage Mix 18](#_Toc2804940)

[Table 10 DLC v 4.4 and Zonal Lumens Distribution Requirements 20](#_Toc2804941)

[Table 11 Industrial Products Efficacy Percentiles from Lighting Facts 23](#_Toc2804942)

[Table 12 Wattage Bin Method (Previous) 24](#_Toc2804943)

[Table 13 Lumen Bin Method (Proposed) 24](#_Toc2804944)

[Table 14 LED High-Bay and Low-Bay Fixtures Base and Measure Wattages 25](#_Toc2804945)

[Table 15 Example Calculation of Fixture Efficiency and Fixture Lumens 26](#_Toc2804946)

[Table 16 Equivalent LED Lumen Output for Similar Levels of Service 26](#_Toc2804947)

[Table 17 Incremental and Full Measure Cost Equations 29](#_Toc2804948)

# 

# List of Figures

[Figure 1 Web-based LED Price and Efficacy Data for Recessed Troffer/Panel 2’ x 4’ 10](#_Toc2804949)

[Figure 2: NEMA Linear Lamp Penetration, Q2 2017 14](#_Toc2804950)

[Figure 3: Impact of TLEDs on IMC for LED Troffer measures 15](#_Toc2804951)

[Figure 4 Example of Zonal Lumen in the 20 – 50 degrees 20](#_Toc2804952)

[Figure 5 HPT8/T5 Linear Fluorescent Highbay Fixture Program Data, 2013-2017 22](#_Toc2804953)

**Section 1 General Measure & Baseline Data**

## 1.1 Measure Description & Background

PG&E submitted PGECOLTG178 Revision 3 for Phase 2 review in September of 2017. CPUC staff issued a disposition “PGECOLTG178r3\_DetailedReview\_29Sep2017-final1” in September 2017 with direction to:

1. Develop a standard practice baseline that reflects the typical mixture of efficiency levels that are currently selected in normal replacement situations.
2. Define measure tiers in a way that assigns greater savings for higher performance products and place an efficacy floor on eligible products.
3. Due to the rapid changes in the marketplace, review available products and typical practices at least annually and update the workpaper as the review indicates.
4. Revise measure definitions so that baseline and measure zonal lumen output levels represent similar levels of service.

In early 2018 Commission staff issued workpaper dispositions for many types of LED lighting technologies and collaborative efforts between CPUC staff and PG&E have resulted in the establishment of majority LED as the standard practice baseline for Normal Replacement (NR), New Construction (NC), Capacity Expansion (CE), and Replace-on-Burnout (ROB) measures in exterior, interior high-bay and interior low-bay lighting applications. This direction was effective January 1, 2018 for exterior and parking garage lighting measures, and April 1, 2018 for interior high and low bay lighting measures. For high-bay and low-bay measures in this workpaper, the baseline for LED measures is set at a maximum of 20% linear fluorescent for lower-output luminaires, with decreases in the fluorescent percentage to 10% and 0% as output increases, due to the availability of LED luminaires at high output levels where fluorescent fixture options are less common or non-existent.

At the April 1, 2018 effective date of the disposition, cost research conducted via program data review and web scraping revealed negative incremental measure costs (IMCs) for the existing wattage bin structure. The Commission Staff (CS) expressed that they did not want PG&E to eliminate measures or categories solely due to the cost issue recognizing the market barriers to LED fixture adoption still exist. CS therefore directed PG&E to work with the Ex Ante Review (EAR) team to resolve these issues. Multiple meetings were then conducted between the EAR team and PG&E from March to April to try to resolve the negative IMC issue. In late April, the EAR team accepted PG&E’s proposal of setting IMC at 110% of the rebate values as an interim solution to the issue. On May 7, 2018, Commission staff issued the disposition for PGECOLTG178 approving the interim solution until 12/31/2018, with direction for PG&E to continue with cost research for inclusion in the next revision to the workpaper. On 10/11/2018 CPUC issued Resolution E-4952 extended the interim solution savings through 2019, but not the measure costs. PG&E’s recent research conducted through TRC in September/October 2018 showed the same negative IMC issue between LED fixtures of varying efficacies.

Previously completed and in-progress CA market studies, including Navigant’s LED Non-Residential Lighting Market Characterization and California LED Pricing Analysis discussed in Section 1.5, demonstrate that customers are facing multiple scenarios when choosing to upgrade their lighting. Customers who intend to upgrade their existing high and low bay lighting from non-LED technologies to LED technology are faced with the following two scenarios: a full LED luminaire fixture/retrofit kit replacement or upgrading to tubular LED lamps (TLED). Cost-sensitive customers may choose the less expensive TLED option over the full fixture upgrade to achieve similar levels of service and energy savings. Evidence from SCE & PG&E participation data, NEMA (National Electrical Manufacturers Association) national sales data[[1]](#endnote-2), input from local distribution channels, and the California LED Pricing Analysis Study[[2]](#endnote-3) by Navigant all have suggested that TLEDs are a viable retrofit alternative to full fixture replacements. PG&E has thus incorporated TLEDs in the baseline mix for the high and low bay lighting in this workpaper revision.

In addition, Revision 4 of this workpaper transitions the measure structure from wattage bins to lumen bins, with the intention to focus consumer purchasing choices on desired or equivalent levels of service.

PG&E has provided TLED cost and efficacy data collected in 2018 for the initial R4 workpaper update. Subsequently PG&E conducted additional online web-scraping on TLED cosst and efficacy in February 2019 per the CPUC E-Ante Review (EAR) team’s recommendation. Based on the new data the average TLED cost and efficacy level were revised accordingly. Please see attached file “Copy of TLED Cost Data\_FEB2019.xlsx” for the collected data and revised calculation of the TLED cost and efficacy.

***Catalog Description***

Interior LED High-Bay and Low-Bay Lighting

**Requirements:**

The LED fixture or retrofit kit must be listed in the current DesignLights Consortium’s (DLC) TechnicalRequirements table under the General Category “High Bay” and under the Primary Use Designations as follow: ***[[3]](#endnote-4)***

* 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
* Must replace a lumen equivalent lamp/fixture of higher wattage. (Please refer to Table 1)
* Must be on the DesignLights Consortium (DLC) Qualified Product List[[4]](#endnote-5)

**Exclusions:**

* Fixtures listed under specialty primary uses on the DLC QPL do not qualify for the deemed measures.
* Horticultural installations do not qualify..
* Exterior installations do not qualify..
* Screw-based lamps do not qualify.
* Must meet the minimum efficacy and lumen range listed for the appropriate measure codes in Table 1.

**Table 1 LED High-Bay and Low-Bay Measure Codes**

|  |  |
| --- | --- |
| **Measure Codes** | **Measure Description** |
| LT514 | LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 110 LPW and < 130 LPW |
| LT515 | LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 110 LPW and < 130 LPW |
| LT516 | LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 110 LPW and < 130 LPW |
| LT517 | LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 110 LPW and < 130 LPW |
| LT518 | LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 110 LPW and < 130 LPW |
| LT519 | LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 110 LPW and < 130 LPW |
| LT520 | LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 120 LPW and < 130 LPW |
| LT521 | LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 120 LPW and < 130 LPW |
| LT522 | LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 125 LPW and < 135 LPW |
| LT523 | LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 125 LPW and < 135 LPW |
| LT524 | LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 125 LPW and < 135 LPW |
| LT525 | LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 125 LPW and < 135 LPW |
| LT526 | LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 130 LPW |
| LT527 | LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW |
| LT528 | LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 130 LPW |
| LT529 | LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 130 LPW |
| LT530 | LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 130 LPW |
| LT531 | LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 130 LPW |
| LT532 | LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 130 LPW |
| LT533 | LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 130 LPW |
| LT534 | LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 135 LPW |
| LT535 | LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 135 LPW |
| LT536 | LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 135 LPW |
| LT537 | LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 135 LPW |

***Program Restrictions and Guidelines***

This workpaper details the savings associated with implementation of energy efficient LED High-Bay/Low-Bay fixtures and retrofit kits. The delivery methods allowed include Downstream, Midstream, and Direct Install Programs for non-residential customers.

The LED fixture or retrofit kit must be listed on the currently applicable DLC’s Technical Requirements under the General Application “High Bay” and one of the 5 following Primary Use Designations ***[[5]](#endnote-6)* :**

* 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

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 code descriptions in Table 1.

**Terms and Conditions:**

The customer must be a non-residential PG&E electric customer.

**Market Applicability:**

The customer must be a non-residential PG&E electric customer.

## 1.2 Technical Description

The following is a short excerpt from the CALiPER Snapshot for Industrial Luminaires[[6]](#endnote-7) 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.*

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 2000’s 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. Improvements in LED performance, makes LED fixtures and retrofit kits an ideal replacement of HID and fluorescent light fixtures.

Though only 6% of all industrial luminaire installations were LED in 2015, market penetration is expected to grow to 86% by 20354. According to LED Lighting Facts, by 2014, LED efficacy had surpassed the HID and fluorescent technology with very competitive pricing.  LED Lighting Facts lists more than 12,000 industrial products, and a majority of listed industrial fixtures have comparable lumen output and higher luminous efficacy than their metal halide and fluorescent counterparts. In terms of color quality and power quality, LED industrial fixtures almost all offer improved performance compared to their metal halide equivalents, and comparable performance to their fluorescent counterparts.”

LED fixtures under this workpaper are assigned a measure code according to efficacy and lumens, which describes the energy savings associated with their replacement of linear fluorescent fixtures and less efficient LED fixtures.

## 1.3 Installation Types and Delivery Mechanisms

The Database for Energy Efficiency Resources (DEER) developed by the California Public Utilities Commission defines the measure application type as shown in the table below:

Table  Measure Application Type[[7]](#endnote-8)

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| *NR* | *Normal Replacement* | *measure applied when existing equipment fails or maintenance requires replacement* |
| *NC* | *New Construction* | *measure applied during construction design phase as an alternative to a code-compliant standard design* |
|  |  |  |

All the measures within this workpaper are calculated for NR.

The workpaper supports Programs with a downstream and direct install delivery channel with normal replacement application types. There are potential plans for a midstream expansion in the future.

Table Delivery Method and Applicable Building Types

|  |  |  |
| --- | --- | --- |
| **Delivery Type** | **Applicable Building Types** | **Application Type** |
| Downstream, Midstream, & Direct Install | DEER Building Types | NR |

## 1.4 Product Base Case and Measure Data

The measure parameters are defined by the fixture initial light output, grouped into lumen bins, and by fixture efficacy in one of 2 eligible Tiers. Linear fluorescent fixtures were included in the base case at up to 20%, in accordance with the May 2018 Interim Solution values approved through 2019. Linear LED replacement lamps (TLEDs) are a new addition to the base case mix with this revision. The corresponding linear fluorescent base cases are chosen by closest match in maintained zonal lumens to a common federal-standard-compliant T8 linear fluorescent fixture of either 2, 3, 4, 6, 8, or 10 four-foot lamps. More information on the base case and measure case calculations is provided in Section 2 Calculation Methods. More information on including TLEDs in the base case is presented in Section 1.5.

### 1.4.1 DEER Data

This revision R4 of the workpaper is an update to the current revision R3 now found in the Database for Energy Efficient Resources (DEER).

Table DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **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 | DEER 2019 |
| Reason for Deviation from DEER | DEER does not contain these exact wattage ranges for the measure; DEER does not contain the percentage mix and efficacies for the base case. |
| DEER Measure IDs Used | Yes |

**Net-to-Gross Ratio**

DEER 2019 provided the relevant NTG value for the measures in this work paper as listed below:

Table Net-to-Gross Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Delivery Method** | **NTGR** |
| NonRes-In-Ltg-LEDFixt | Nonresidential interior hardwired LED fixtures using delta-Watts savings methods. The full NTG value of 0.91 shall be used for the above code savings. | Com | Any | All | 0.91 |

**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 these measures in this work paper is in the table below.

Table Installation Rates

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Com-HiBay-PGE | Non-Res High-Bay; Annual Installation Rate | Com | Any | NonUpStrm | 0.92 |

**Hours of Operation**

The DEER 2016 hours of operation and interactive effects are used in the savings calculations.

**Effective Useful Life / Remaining Useful Life**

The rated life for these products is assumed to be 50,000 hours, the minimum DLC specification, though DLC products average more than 56,000 hours. Rated life for DLC-listed products starts at 50,000 hours and extends much higher, but a minimum of 50,000 hours or 12 years is used here. Since the EUL is dependent on the hours of operation, the EUL varies by building type.

The EUL is based on 50,000 hours rated fixture life divided by average annual hours of operation for each building type:

EUL = (DLC-Minimum Fixture Life (hours)) / (Average Operating Hours per Year)

Table Effective Useful Life/Remaining Useful Life

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| ILtg-Com-LED-50000hr | LED Fixture - Indoor- Commercial | Com | Lighting | 12 | 4 |

**1.4.2 Codes & Standards Analysis**

***Title 20:*** The ballast efficiencies of metal halide lighting systems are regulated under 2016 Title 20 Appliance Efficiency Regulations, section 1605.3(n)[[8]](#endnote-9), but these products have been entirely removed from the base case of this workpaper.

***Title 24:*** Neither the source technology nor the fixture selection for these measures falls under Title 24 [2016] [[9]](#endnote-10) of the California Energy Regulations. However, the Lighting Power Densities (LPD) in watts/ square feet of both measure and base case are capped by Title 24. Given the enormous range in high bay spacing, with 25 and 30 foot spacing possible, any eligible fixture under this measure (capped at 283 W/fixture) could meet appropriate LPDs listed in Table 140.6-C of Title 24. The bases of the 2016 standards for high and low bay occupancies are pulse start metal halide.  The 2019 Title 24 standards will be based on all LED designs.

***Federal Standards:*** These measure case fixtures do not fall under Federal DOE or EPA Energy Regulations. Metal Halide fixtures are no longer part of this workpaper base case mix.

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

The following studies were used for the development of the workpaper and briefly described below:

### 1.5.1 Lighting Dispositions

There were three lighting dispositions that were issued relevant to the development of this workpaper:

* PGECOLTG178r3\_DetailedReview\_29Sep2017-final1.pdf (Issued September 29, 2017)
* High Bay Fixtures Disposition\_03262018.docx-1.pdf (Issued March 26, 2018)
* InteriorHighAndLowBayLEDPhase2-7May2018-Final (Issued May 7, 2018)

As outlined in the “Disposition for Workpaper PGECOLTG178-REV3 Covering High and Low Bay LED Fixtures” dated September 29, 2017, the PAs will address the following:

1. *Develop a standard practice baseline that reflects the typical mixture of efficiency levels that are currently selected in normal replacement situations.*
2. *Define measure tiers in a way that assigns greater savings for higher performance products and place an efficacy floor on eligible products.*
3. *Due to the rapid changes in the marketplace, update the measures at least annually.*
4. *Revise measure definitions so that baseline and measure zonal lumen output levels represent similar levels of service.*

In the InteriorHighAndLowBayLEDPhase2-7May2018-Final” disposition, PG&E was directed to do the following:

* *Required to work with Commission Staff over the course of next few days to develop interim ex ante values that will become effective April 1, 2018.*
* *Encouraged to continue to engage with Commission staff if there is continued uncertainty regarding how PG&E can meet the compliance requirements within the September 29, 2017, staff disposition.*
* *Shall work with Commission staff and their consultants to develop interim ex ante value ASAP over the next two weeks that allow a resubmission of R3 using those interim values until more robust standard practice baseline work can be completed.*

As a result of these dispositions, R3 of this workpaper was created in April 2018 to reflect the agreed upon interim approach. This revision, R4, adds a conversion of the measure structure from wattage bins to lumen bins, and the addition of TLEDs to the base case mix.

### 1.5.2 California LED Pricing Analysis, Navigant 2018[[10]](#endnote-11)

This market study to evaluate LED product pricing was completed by Navigant Consulting, Inc. in January 2018. This study’s objectives included 1) identifying the range of current prices for DLC and ENERGYSTAR qualified LED products in the California non-residential lighting market for certain priority product categories selected by the IOUs including the LED Highbay/Lowbay lighting product category, 2) determining what factors significantly influence LED price, 3) developing an incremental cost estimate relative to identified baseline technologies (MH, HPS, LF, CFL), and to 4) determine how, and at what rate LED price ranges are anticipated to change as the market matures 3 and 5 years out from 2017.

Price data from 2016 Q4 and 2017 Q2 was collected from California IOU Program data and from Navigant Research’s LED Price Tracker, which utilizes web-scraping software to collect data on product pricing and specifications online. Of the LED products, only those that met DLC’s technical requirements were included in the study analysis. To determine which factors significantly influence LED prices, a multiple variable regression was conducted to determine the correlation between various product specifications and price.

The results of the study initially showed that the biggest driver influencing LED price is lumen output, followed by manufacturer, DLC qualification, and CRI. Efficacy was not one of the significant price determining characteristics. Furthermore, even as DLC efficacy requirements have increased over time, prices have continued to decline. According to the study, price does not appear to scale with efficacy for any of the LED product categories evaluated, including LED Highbay/Lowbay Lighting. LED deemed lighting measures have assumed that measure costs have scaled with efficacy, therefore this finding that efficacy may not be a key price driver implies that further analysis should be conducted to consider how to incorporate other price drivers in measure design to encourage the adoption of higher degrees of efficiency. PG&E will consider a measure structure that is tiered by both lumen output and efficacy in future workpaper updates that may include separate efficacy tiers. Further research studies to explore and understand the barriers to market adoption other than pricing are needed for future workpaper updates.

Figure 1 below (Figure 3-5 in study) shows that the relationship between price and efficacy is highly randomized and there is a large spread in the dataset. Although the Figure shows LED troffers, this phenomenon can be seen across the other lighting categories as well.



Figure Web-based LED Price and Efficacy Data for Recessed Troffer/Panel 2’ x 4’

(Source: California LED Pricing Analysis, Navigant, January 2018)

Lumen output and wattage have a direct relationship, increasing or decreasing proportionally. Therefore, the study’s indication that lumen output is a main driver of LED prices can also be interpreted that wattage may be a primary price driver. Since both factors could not be tested simultaneously due to their collinearity, only one was tested. Increasing lumen output in a product would also require increasing power load which could lead to eventually more drivers or more sophisticated drivers, which adds cost to the LED product. This supports traditional IOU Program rebate structure of offering higher incentives for higher wattage products because as wattage increases, so does product purchase price.

The study also noted that the cost to manufacture a product is separate from the consumer purchase price of that product. So, although it may cost more to increase the efficacy of a product, that additional cost is not being reflected in the purchase price the way lumen output/wattage and manufacturer affect product price. It could be that manufacturers are making trade-offs with other performance parameters to keep prices down as they improve efficacy, but that was not evaluated in this study and could be important future research to better understand the factors that influence LED price.

Another important finding of this study was that a larger portion of retrofit installations include replacing lamps and ballasts only and not entire fixtures. This is due to the extremely long life of commercial baseline (MH, HPS, induction, linear fluorescent) fixtures. This finding has implications for this workpaper, and suggested that a base case mix other than 100% fixture-to-fixture is appropriate. In addition, the incremental measure cost in the two scenarios is very different. Since a common consumer purchasing scenario includes replacement lamps and ballasts only, this workpaper has been modified to consider that scenario in the baseline.

The study determined that prices will continue to decrease over the next 5 years; however, the rate of decline is slowing across all product categories. It will continue to be important to closely monitor LED prices and update workpapers at least annually.

### 1.5.3 LED Workpaper Update Study, Navigant 2015[[11]](#endnote-12)

The LED Workpaper Update Study, also conducted by Navigant Consulting Inc from 2015 was similar to the study completed in 2018. Its objective was to develop findings and recommendations for updates to key parameters and methodologies used in the workpapers, program planning, and parts of the DEER database that target light-emitting diodes (LEDs), to ensure that IOU lighting programs can keep up with rapid changes in LED pricing and efficacy.

Three key research topics for high priority LED product categories were 1) LED pricing (for both residential and non-residential products), 2) Non-residential baseline wattages (which inform the selection of appropriate wattage reduction ratios or wattage ranges), and 3) the ability of the currently used savings estimation methods to predict non-residential baselines (e.g., wattage reduction ratio and wattage ranges).

Price data was collected through web-scraping, market-actor surveys of contractors, distributors, and commercial end-users, and through in-depth interviews with manufacturers and retailers. The study developed price estimates that were current for 2015, and it also looked at factors that affect pricing and how often workpapers need to be updated to include most current pricing.

The 2015 study found higher annual percentage price declines for LED products which have since slowed down as shown in the 2018 study. While annual decreases for LED luminaires were found to be 20% per year from 2015-2018, they are now expected to be 9% per year from 2017-2020, decreasing to 8% per year from 2020-2022 on average across all product categories. However, accuracy of these price projections may be limited due to the small dataset. The study suggested price assumptions be updated annually using web-scraping until prices stabilize. This will help ensure projections of LED price remain useful to the IOUs. The study also found that regional price differences in California are negligible and so all IOUs can use the same cost data in workpapers.

In terms of factors that influence the price of luminaires, no one factor was found to significantly affect pricing, but there were many: efficacy, lumens, watts, CRI, lifetime. This analysis was repeated in the 2018 pricing study and correlation factors were assigned and lumen output/wattage was determined to be the greatest influence on price. IOU LED deemed lighting measures have assumed that measure costs have scaled with efficacy, therefore this finding that efficacy may not be a key price driver implies that further analysis should be conducted to consider how to incorporate other price drivers in measure design to encourage the adoption of higher degrees of efficiency.

The projected LED price decline is expected to have a significant impact on LED adoption in California. The forecasted installed stock penetration of LEDs into the highbay/lowbay applications is expected to increase from 3.4% in 2015 to 17% in 2018, and then increase to 34% in 2020. IOU Programs can help accelerate this adoption curve and encourage the adoption of higher and highest efficiency products.

Market actors said that lumen equivalence was the single most important factor when selecting an LED. End users also considered light color and wattage equivalence when selecting an LED fixture. It will be important to research and understand how customers perceive lumen equivalence in LED fixtures and if there is bin jumping similar to what reportedly occurs with LED lamps – when market actors choose an LED that does not align with its rated wattage or lumen equivalent. We hope the new measure structure change to lumen bins in this workpaper revision will help emphasize light output as the most important metric in product selection.

When Navigant considered the incidence of early retirement, the results showed that the majority of contractors and end users indicated that they are more likely to replace equipment before the end of useful life with LEDs. This suggests that LED decision making is unique and warrants additional research on ER and NR baselines. The IOUs are considering incorporating early retirement measures into future workpaper updates to capture the additional energy savings potential in the market.



**Figure 2: Willingness to replace equipment with LEDs before end of useful life, relative to other replacements (Source: California LED Workpaper Update Study, Navigant, August 2015)**

Early retirement baseline according to contractors indicates closer to 50% for HID technology and 50% for T8 and T5 combined.

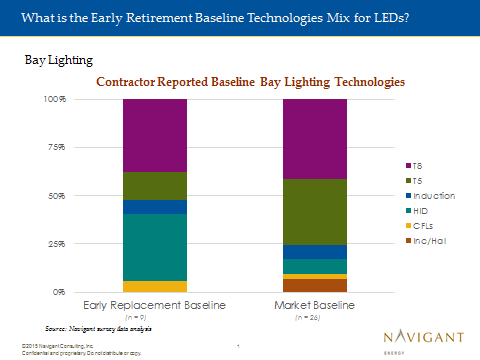


Figure 3: Early Retirement Baseline Technology Mix for LEDs as reported by Contractors

Survey data and specifications on existing fixtures also indicate that LEDs replacing metal halides and linear fluorescents are not near the upper end of the LED wattage ranges in the May 30, 2014 lighting disposition. The Navigant study results and IOU program data analysis point out that the majority of program activity happens in the lower wattage ranges for PG&E and it would be advisable for IOUs to break these measure codes into narrower wattage ranges to more accurately capture savings.

This revision of the workpaper breaks the measure codes into narrower bin sizes to more accurately capture savings and going forward will also evaluate program data to better understand what lumen/wattage products customers are buying. This program information can then be used to more accurately calculate energy savings. Section **1.6.3 Product ID Collection Process** describes a data collection process to inform savings calculations in the future.

### 1.5.4 LED Non-Residential Lighting Market Characterization, Navigant – In Progress

This Statewide Non-Residential LED Market Characterization Study being conducted by Navigant Consulting, Inc was initially scoped in response to a June 26, 2015 workpaper disposition for PGECOLTG179 LED Ambient Commercial Fixtures and Retrofit Kits, seeking additional clarification on qualifying LED technologies for the IOUs. Its expected completion date is Q1 2019. In that decision, Commission Staff think it is unclear that the DLC QPL meets the requirements of incentivizing the top half of quality products in the non-residential lighting market. In that disposition, Commission Staff wrote the following:

*“However, the products covered by this work paper are not covered by the CEC standard and therefore must still be “products that are in the top half of quality on the market.” As added guidance along with the more general guidance provided by the Commission in the text of the Decision (at 79) that “Our goal, as in D.12-05-015, is to avoid offering incentives for lighting products that do not meet consumer expectations and result in a poor lighting experience, discouraging customers from investing in energy efficient lighting in the future.” It is unclear that the DLC listed products meet this requirement. The work paper shall be revised to include the process utilized by the PAs that will ensure that products offered meet the direction from D.12-11-015.”*

This market share study is an effort to determine the size of the non-residential LED market and the relative market share of products on the DLC Product List. The study is also developing a proposed definition of “quality” for non-residential lighting and will work with Commission staff to finalize this quality definition for future use in IOU’s lighting portfolio.

### 1.5.5 TLED Baseline

The TLED base case proposed here is based on evidence from the pricing study above, incentive program performance in SCE & PG&E territories, NEMA national sales data, and input from local distribution channels. All data sources suggest that TLEDs are a popular retrofit alternative to the purchase of new luminaire or luminaire retrofit kit.

In normal replacement scenarios, customers who intend to upgrade to LED technology can choose either to replace the entire fixture with a new LED luminaire or fixture retrofit kit, or replace linear fluorescent lamps with linear LED lamps (aka TLEDs). Customers who intend to upgrade their existing non-LED technologies to LED technology are faced with the two scenarios that Navigant highlights: a full LED luminaire fixture/retrofit kit replacement or upgrading to TLEDs. Cost-sensitive customers may choose the less expensive TLED option; coupled with the data that indicates steady increases in TLED market penetration, PG&E thus believed it is reasonable to include TLEDs as part of the NR baseline scenario.



Figure : NEMA Linear Lamp Penetration, Q2 2017

NEMA shipment data shows that TLED purchases have been increasing over the last several years compared to other linear lamp types (see Figure 2 above).[[12]](#endnote-13) Much of that popularity is driven by low cost (for similar levels of energy savings), significantly lower costs than the costs of both baseline and measure case new LED luminaires and retrofit kits.

The baseline share of LED tubular replacement lamps (TLEDs) is estimated at a significant share, up to 20%, with the value in each lumen bin equal to the fluorescent baseline share because as fluorescent fixtures are no longer suitable for very high output products, the lampholders that TLEDs require will also not be available for the highest output highbays. Bonneville Power Administration (BPA) conducted a Non-Residential Lighting Market Characterization Study for the Pacific Northwest Region indicated that LED sales continue to increase rapidly, accounting for 15% of all non-residential sales, with LED lamps and tubes representing the majority of the growth at 10% of total sales.[[13]](#endnote-14) The 20% TLED scenario is also a balance point which yields positive IMCs as well as enough savings for a cost-effective program. PG&E will review program data in mid-year 2019 along with other publicly available study/data to determine if the TLED percentage requires update.

#### **TLEDs as a Viable Retrofit Alternative to Full Fixture Replacement**

The 2018 California LED Pricing Analysis by Navigant distinguishes the lighting luminaire market from the replacement market, and suggests that customer purchase decisions are not solely influenced by fixture cost differentials but include other options such as lamps that also deliver energy savings.

As Navigant’s key findings suggest, and as shown in Figure 3 below, the inclusion of TLEDs has a significant effect on incremental costs for these measures. In this workpaper, TLEDs are much less expensive than either base case (97+ lm/W) or measure case (110+ lm/W) LED products.

Figure : Impact of TLEDs on IMC for LED Troffer measures

With an increasing percentage of TLEDs in the base case, a positive IMC starts to emerge, which more accurately represents the proportion of the market that is the replacement market as explained by Navigant. (For more details on the calculations, please refer to the latest calculation file and vary the TLED base case share on the ‘NR’ worksheet). A similar trend also exists for LED Troffers, Linear Ambient fixtures, and Parking Garage fixtures.

***TLED market share: Costs Continue to be a Barrier to Customer Purchase Decisions***

Customers who intend to upgrade their existing non-LED technologies to LED technology are faced with the two scenarios Navigant highlights, a full LED luminaire fixture/retrofit kit replacement or upgrading to TLEDs. Cost-sensitive customers may choose the less expensive TLED option; coupled with the data that indicates steady increases in TLED market penetration, PG&E believes this should reasonably be included as part of the NR baseline scenario.

Bonneville Power Administration (BPA) conducted a Non-Residential Lighting Market Characterization Study for the Pacific Northwest Region that indicated that LED sales continue to increase rapidly, accounting for 15% of all non-residential sales, with LED lamps and tubes representing the majority of the growth at 10% of total sales.[[14]](#endnote-15) There are two Statewide EM&V studies that will help provide additional California-specific data to support this assumption:

* **California Statewide Non-Residential LED Quality and Market Characterization Study:** see Section1.5.4 LED Non-Residential Lighting Market Characterization, Navigant – In Progress.
* **Statewide Non-Residential Interior Lighting Standard Practices Study:** This study is still in the scoping phases and addresses Commission Staff requests for more forward-looking baseline trends for baseline updates.

#### **Proposed Blended Baseline Mix: 100% LED Technology based upon full LED luminaire fixtures/retrofit kits + TLEDs**

For PGECOLTG178, DEER2019 continues the approved baseline of up to 20% linear fluorescent and 80% LED technologies. PG&E proposes that this 80% LED be divided into a blend of up to 20% TLEDs and 80% new LED luminaires and retrofit kits for the LED technology base case.

Figure 4 below illustrates the proposed workpaper methodology adding TLEDs to the baseline scenario as part of a blended baseline.

#### **History of Blended Baseline Approach Development**

PG&E’s early 2018 research and communications with the CPUC EX-Ante Review Team noted challenges with negative IMC values as baseline technologies shift to LED - the same technology as the measure case.[[15]](#endnote-16)

The EAR team expressed that they did not want PG&E to eliminate measure codes or categories solely due to the cost issue recognizing the market barriers to LED fixture adoption still exist. Multiple meetings were then conducted between the EAR team and PG&E from March to April to try to resolve the negative IMC issue. In late April, the EAR team accepted PG&E’s proposal of setting IMC at 110% of the rebate values as an interim solution to the issue. On May 7, 2018, Commission staff issued the two dispositions for PGECOLTG151 & PGECOLTG178 approving the interim solutions, with direction for PG&E to continue with cost research for inclusion in the next revision to the workpaper. PG&E’s recent research conducted with TRC in September/October reveals the continuation of the negative IMC issue.

In conversations with the Ex Ante Review (EAR) Team from April 4, 2018 & April 5, 2018, in development of the interim solution workpaper for LED High-Bay and Low-Bay fixtures, the EAR team acknowledged TLED popularity in the market and alluded to PG&E considering adding TLEDs to its baseline mix for fixtures that have had fluorescent T8s in their baseline history.[[16]](#endnote-17)

As such, PG&E is proposing to add linear LED replacement lamps to its baseline technology mix for this lighting workpaper as well.

### 1.5.6 CALiPER Snapshot Report June 17, 2016:[[17]](#endnote-18)

Results that CALiPER reported in its most recent snapshot report on TLEDs:

* Over 90% of the currently listed TLEDs exceed 100 lm/W, which is roughly the efficacy of a bare linear fluorescent lamp, which is close to the qualification threshold for the DesignLights Consortium™ Product List of 110 lm/W. In the broad LightingFacts database, both LED troffer retrofit kits and LED troffer luminaires tend to have lower efficacies compared to bare TLEDs, but when luminaire efficiency is considered, the retrofit kits and troffers are comparable to the high end of TLED efficacy.
* When evaluating TLEDs, it is important to consider their efficacy when installed in a luminaire. As the number of lamps increases, the luminaire efficiency is slightly reduced. In order to appropriately compare the efficacy of TLEDs to that of other LED luminaires, this workpaper uses a fixture efficiency multiplier of 0.8 to represent the luminous efficiency of the luminaire, per this CALiPER report from the DOE.

Based on the recent data collected in February 2019, the 25th percentile of the TLED efficacy is determined to be 111 lm/W and is adopted for this workpaper revision. See attached file “Copy of TLED Cost Data\_FEB2019.xlsx” for the collected data and the calculation of the TLED efficacy.

In addition, many TLEDs operate with pre-existing fluorescent ballasts, which increases wattage. CALiPER does not address the percentage of TLEDs operating with fluorescent ballasts. Anecdotal market evidence suggests the plug-and-play, Type A, approach to TLEDs is the most popular, with no electrician requirement to plug in new lamps; this is also the most inefficient strategy because it leaves the fluorescent ballast powered. Without a thorough study available on TLED trends, the work paper assumes a conservative 40.4% of TLEDs operate with fluorescent ballasts, based on the percentage of the DLC listed TLEDs that are Type A. Fluorescent ballasts are assumed to consume 10% of system power, based on federal fluorescent ballast luminous efficiency standards cited above in section 1.5.2. 59.6% of TLEDs are assumed to have no ballast losses. Incorporating ballast wattage and fixture efficiency losses yields an efficacy of 85.2 lm/W for TLEDs in fixtures.

### 1.5.7 CALiPER Summary Report October, 2011:

The DOE Solid-State Lighting CALiPER Reports examined 7 LED high-bay fixtures combined in application summary reports #13[[18]](#endnote-19). None of the 7 fixtures met the DLC minimums for efficacy and output. Given the small population relative to the full DLC QPL of 75,304 products as of 12/2018, CALiPER reports were not used for determining equivalency. Wattage equivalency was based on the full list of DLC products. CALiPER has not published a full application report on high-bay LEDs since report #13.

## 1.6 Data Quality and Future Data Needs

## 1.6.1 Standard Practice Baseline Studies

**Indoor LED Lighting**

Previous revisions of this workpaper focused on the replacement of metal halide or linear fluorescent fixtures with LED technology. The baseline assumed 100% metal halide or 100% linear fluorescent in previous measures.

The September 2017 high-bay and low-bay disposition directed an update to reflect standard practice baseline for normal replacement situations. As such, the California Investor-Owned Utilities originally intended to leverage the PG&E-led “Non-residential Lighting Market Characterization Study” mentioned in Section 1.5.4 that is wrapping up in March 2019 by Navigant Consulting, Inc. to gather 2017 and projected (5 years) sales data that could inform the standard practice baseline for interior LED categories. However, the Market Characterization Study could not accommodate this latter scope and a separate “Statewide Interior Lighting Standard Practices Study” launching in March 2019 will be conducted by TRC Energy Services that will investigate standard practices for interior lighting categories of Troffers, Downlights, and Highbay-fixtures. It will also explore the various retrofit paths for a linear fluorescent fixture, in particular for troffers (lensed and parabolic) and linear fluorescent high/low-bay fixtures, and what rate the market is choosing each of these retrofits. These retrofit paths have significantly different costs, and consequently significantly different IMCs, and potentially different energy savings.

Results from this Interior Lighting Standard Practices Study could help to inform future iterations on the blended baseline mix for LED technologies. The table below is the breakdown of technology use for the base case used in the savings calculations, to be used until further study data is available.

Table Base Case Technology Percentage Mix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Description** | **Measure Case Tier** | **Base Case**  **% Linear Fluorescent** | **Base Case % TLED** | **Base Case**  **% LED** |
| LT514 | LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT515 | LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT516 | LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT517 | LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT518 | LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT519 | LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 110 LPW and < 130 LPW | Tier 1 | 20% | 20% | 60% |
| LT520 | LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 120 LPW and < 130 LPW | Tier 1 | 10% | 10% | 80% |
| LT521 | LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 120 LPW and < 130 LPW | Tier 1 | 10% | 10% | 80% |
| LT522 | LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 125 LPW and < 135 LPW | Tier 1 | 10% | 10% | 80% |
| LT523 | LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 125 LPW and < 135 LPW | Tier 1 | 0% | 0% | 100% |
| LT524 | LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 125 LPW and < 135 LPW | Tier 1 | 0% | 0% | 100% |
| LT525 | LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 125 LPW and < 130 LPW | Tier 1 | 0% | 0% | 100% |
| LT526 | LED HighBay luminaire rated from 4500 to < 5400 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT527 | LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT528 | LED HighBay luminaire rated from 6500 to < 7800 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT529 | LED HighBay luminaire rated from 7800 to < 9400 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT530 | LED HighBay luminaire rated from 9400 to < 11800 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT531 | LED HighBay luminaire rated from 11800 to < 14800 lumens and >= 130 LPW | Tier 2 | 20% | 20% | 60% |
| LT532 | LED HighBay luminaire rated from 14800 to < 18500 lumens and >= 130 LPW | Tier 2 | 10% | 10% | 80% |
| LT533 | LED HighBay luminaire rated from 18500 to < 23100 lumens and >= 130 LPW | Tier 2 | 10% | 10% | 80% |
| LT534 | LED HighBay luminaire rated from 23100 to < 30000 lumens and >= 135 LPW | Tier 2 | 10% | 10% | 80% |
| LT535 | LED HighBay luminaire rated from 30000 to < 39000 lumens and >= 135 LPW | Tier 2 | 0% | 0% | 100% |
| LT536 | LED HighBay luminaire rated from 39000 to < 50700 lumens and >= 135 LPW | Tier 2 | 0% | 0% | 100% |
| LT537 | LED HighBay luminaire rated from 50700 to < 65900 lumens and >= 135 LPW | Tier 2 | 0% | 0% | 100% |

### 1.6.2 Inclusion of Early Retirement (ER)/Accelerated Replacement (AR) Measure Application Type

The IOUS are currently investigating ER/AR measure application type offering for the next iteration of the workpaper. The analysis will be derived from reviewing market studies, ER custom applications with a focus on customer segment(s) and geographical location(s). Resolution E-4818 and Track 2 Working Group begins to set a framework for deemed program level ER adoption for Preponderance of Evidence. Further Commission Staff guidance on ER will be forthcoming and incorporated into the final development of ER measure application type for deemed.

Subsequently CPUC issued an E-4939 Draft Comment Resolution on October 11, 2018, addressing Track 2 Working Group related energy efficiency issues pursuant to D.16-08-019 and Resolution E-4818. In the draft Resolution E-4939’s section 3.2.3 Task 3 Conclusions stated “…..However, as to the proposal’s evidentiary requirements for demonstration of equipment viability and program influence, the POE requirement to demonstrate equipment viability and program influence for accelerated replacements shall meet the requirements in Task 2 to be addressed in a future resolution” (last paragraph on p.27).

### 1.6.3 Product ID Collection Process

As part of the IOUs’ future data needs, a more robust process to collect product information from program data is being implemented. It has been an ongoing challenge to run data analytics on existing Program data due to model number discrepancies from rebate application invoices and the DLC QPL. In order to address this challenge, IOUs propose to collect the unique DLC product ID in rebate applications. This unique identifier has no variation and can easily be used to match product information from program data to the performance metrics of these products listed on the DLC QPL. Collecting this additional information will allow IOU Programs to analyze program data for cost and savings calculations for future workpaper updates.

### 1.6.4 Lighting Facts LED Database

Lighting Facts offers many benefits as a data source for a full characterization of the LED market:

* A wide range of product offerings as of March 2018
* Large sample size (~12,500 industrial products)
* Product performance data previously accepted by CalTF and Ex-Ante Review team in the LED Troffer workpaper
* Ability to filter by year, so that older products could be excluded from the efficacy sampling
* Important distinctions by primary use: Lighting Facts captures the lower LPW values typical of Wall-mounted LEDs on the market.

Unfortunately, as of March 31, 2018, the Department of Energy has ended future funding for the Lighting Facts label program. Other data sources will need to be considered in lieu of Lighting Facts such as the data that will be collected for the Navigant LED Market Characterization study.

A total of 2,037 PG&E applications from 2016 – 2018 were matched to DLC products, giving precise cost per output data in all Tiers.

# Section 2 Calculation Methods

### 2.0.1 Equivalent Levels of Service

This workpaper uses the current DLC QPL and LED LightingFacts to choose the most appropriate LED base and measure case performance. The fluorescent base case power consumption uses the Standard Fixture Wattages from Appendix B. The base case fluorescent wattages have been developed from common configurations of high performance T8 linear fluorescent high-bay and low-bay fixtures. The base case LED wattages has been determined by lumen bin values and the 25th percentile efficacy of LightingFacts products.

The fixture lumen performance in the high-bay and low-bay categories of the DLC qualified product list as of December 2018 was analyzed to justify the wattage equivalency assumptions. The 76,109 products in the DLC list in these categories were binned by lumen output, and each bin was analyzed for equivalency to common linear fluorescent base case fixtures based on zonal lumens.

**Zonal Lumens Methodology**

Fluorescent, and LED luminaire lumen equivalence was based on maintained Zonal Lumens in the DLC-designated garage fixture zone of 20 - 50°, as shown in the table below. The zonal lumen methodology analyzes light output in a specific zone to ensure equivalent performance between LED and linear fluorescent fixtures. PG&E’s R3 for this workpaper introduced zonal lumens as a proxy for useful light output. uses the definition from the DesignLights Consortium specified minimum requirement zone: 20 to 50 degrees from nadir.

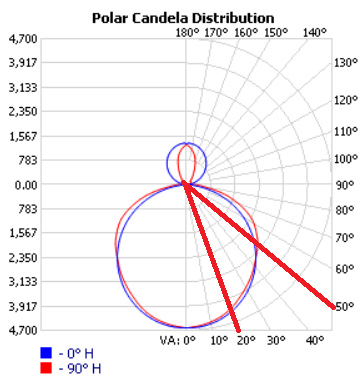


Figure Example of Zonal Lumen in the 20 – 50 degrees

(Source: Visual-3d <http://www.visual-3d.com/tools/photometricViewer/default.aspx?id=18586>)

The savings calculations will continue to utilize Zonal Lumens, as this method approximates the level of service provided by the luminaires at least as well as the other method, and does so without unnecessary complexity.

Table DLC v 4.4 and Zonal Lumens Distribution Requirements

|  |  |  |
| --- | --- | --- |
| **Primary Use Designation** | **Zone Definition** | **Zonal Lumen** **Requirement** |
| High Bay and Low Bay Luminaires and Retrofit Kits | 20-50⁰ | ≥30% |
| High Bay Aisle Luminaires | 20-50⁰ | ≥50% |
| 0-20⁰ | ≤30% |

Many linear fluorescent fixtures commonly over-illuminate the area directly beneath the fixture (0° - 20°) simply because they lack the ability to direct light to where it is needed most. Linear fluorescent sources may achieve a higher average illuminance than an LED source (and have a correspondingly higher lumen output), however they achieve similar minimum illuminance because the LED fixture may be able to do a better job of directing light out to the edges of the illuminated space.

The analysis of lumen performance focuses on light distribution differences from Fluorescent and LED technologies. Fluorescent, as an omni-directional source, is not as successful in effectively spreading out light and avoiding pools of light below each fixture, which is sometimes seen in product data as a higher percentage of lumens in the 0 - 20° zone. This analysis estimates the degree to which LEDs with better directional light control can replace fluorescent products with higher total light outputs. The same data from Revision 2 of the workpaper is used for this update as the fundamental relationships of light distribution have not changed.

This analysis compares fixtures based on the lumen output in the 20° - 50° range to ignore the hot spot of light that may appear directly under a fixture. Customers are often happy with the light output of LED fixtures with lower total light output than the linear fluorescent fixtures replaced which further supports utilizing the zonal lumen method.

The lumens in the 20° - 50° range were calculated from the DLC QPL based on the measured light output of each fixture multiplied by the percent of lumens in that range labeled on the DLC QPL spreadsheet at ZL-HBLB: 20-50 or ZL-HBA: 20-50. The lumen output for base case fixtures in the 20° - 50° range was calculated from the zonal lumen summary tables of manufacturer photometric reports. These values were corrected for lamp lumens and ballast factor based on federal standards for T8 linear fluorescent lamps.

The lumen output in the 20° - 50° range is the basis for the division of LED products into appropriate measure codes. The LED products equivalent in lumen output in the 20° - 50° range were grouped to the base case fixtures as much as possible, given the limitation of varying LED fixture performance. The HPT8 linear fluorescent fixtures were compared to the group of DLC-approved LED fixtures that would best replace the linear fluorescent fixtures based on photopic lumens in the 20° - 50° zones. Measure codes were created by setting LED wattage ranges from the lumen equivalence of the base case fixture lumen output.

The DLC QPL was analyzed as of November 2018 to determine qualification of the applicable fixture population. 47,230 fixtures in these categories, 80% of the qualified products, are represented in the measure code offerings. There are no measures codes in the first efficacy tier above 203 W because the base case efficacy above that wattage approaches the measure case efficacy floor thereby generating minimal energy savings. Only DLC Premium products at or above 130 LPW create substantial savings above the base case in the higher wattage ranges.

### 2.0.2 Assumptions Used in the Calculations

**Base Case Technology Mix**

PG&E evaluated past program data to estimate a starting point for the base case technology mix. PG&E previously offered rebates for HPT8/T5 linear fluorescent highbay fixtures. The figure below shows program activity for these measures.

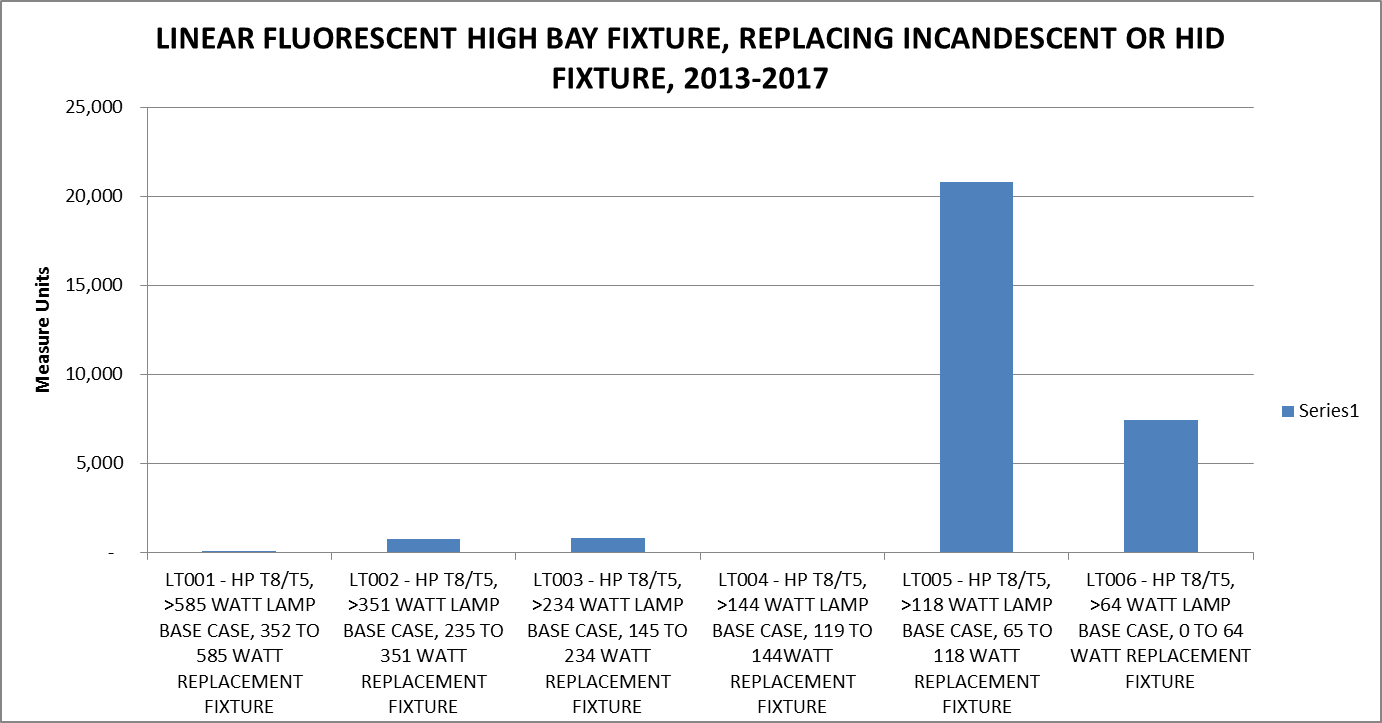


Figure 5 HPT8/T5 Linear Fluorescent Highbay Fixture Program Data, 2013-2017

This data makes clear that the majority of purchases in this measure offering occur in the lower wattage ranges from 0-118 watts. This implies that when customers are selecting fixtures to purchase in an ROB scenario, it is more likely to be fluorescent in the lower wattage bins than higher wattage bins. This is the basis for the base case mix chosen in this revision of the workpaper – starting with higher percentage fluorescent fixtures in the lower wattage ranges and dropping that percentage of fluorescent fixtures as the wattage increases.

Although the measure codes are not separated for lowbay and highbay applications specifically, the measures are separated by lumens/watts and lowbay applications tend to occur in the 0-10,000 lumen range (the equivalent of 2,3, and some 4 lamp linear fluorescent fixture replacements) whereas highbay applications fall into the higher lumen ranges. The standard practice baseline for these lower wattage range measures are 20% linear fluorescent and 80% LED. For the 6, 8, and 10-lamp linear fluorescent equivalent measures, mostly high bay applications, the standard practice baseline technology mix shows 90% for LED and 10% for linear fluorescent. Measures above the 10-lamp linear fluorescent fixture assume 100% LED standard practice baseline as linear fluorescent fixtures are not common at all at this high lumen output. Historically, metal halide fixtures were used in these applications.

During discussions with the Commission Staff, it was made apparent that LED linear lamps (also known as TLEDs) should be acknowledged as a major part of the standard practice baseline. TLEDs are now included and the base case technology mix is shown in section 1.6.1:

Table 9 Base Case Technology Percentage Mix.

**LED Base Case Efficacy:**

The base case efficacy used was 25th percentile from Lighting Facts for industrial luminaires. This is a similar approach taken in the workpaper PGECOLTG151 Outdoor Area and Street Lighting. This assumption is based on what customers would buy in the absence of utility programs.

Table Industrial Products Efficacy Percentiles from Lighting Facts

|  |  |  |
| --- | --- | --- |
| **Base Case**  **25 %ile efficacy** | **Tier 1 Floor**  **(approx. 50 %ile efficacy)** | **Tier 2 Minimum**  **(approx. 75 %ile efficacy)** |
| 96.0 | 110 | 130 |
| 95.0 | 110 | 130 |
| 100.3 | 110 | 130 |
| 97.1 | 110 | 130 |
| 98.9 | 110 | 130 |
| 106.5 | 110 | 130 |
| 105.3 | 120 | 130 |
| 109.5 | 120 | 130 |
| 115.8 | 125 | 135 |
| 113.9 | 125 | 135 |
| 110.3 | 125 | 135 |
| 110.9 | 125 | 135 |

**Linear Fluorescent:** The wattages used are from Appendix B Standard Fixture Wattages. It is assumed to use HPT8 lamps (3050 lumens per Federal Standards) with a ballast factor of 1.15.

**TLED Base Case and TLED Fixture Efficacy:**

The data collected in February 2019 of the 62 (excluding the one highest cost outlier) new TLED models shows an efficacy range of 100 to 160 LPW.  Resolution E4952 states that the code/standard practices baseline assumes performance equal to the 25% percentile. The 25% percentile of the 62 TLED models is calculated at 111 LPW (see attached file “Copy of TLED Cost Data\_FEB2019.xlsx” for the calculation). Using the 111 LPW efficacy the TLED fixture efficacy is then calculated to be 85.2 LPW (see attached file “PGECOLTG151 R9 LED Outdoor Ltg Calc\_ Rev 2.xlsx” for details of the calculation).

**LED Measure Case Efficacy:**

Measure case efficacy used was chosen after a comparison of two data sources: LightingFacts 50th percentile efficacies and DLC Standard minimum efficacies. Base case efficacies chosen around the LightingFacts 50th percentile are always higher than DLC Standard-tier minimum technical requirements (105LPW for version 4.3).

### 2.0.3 Measure Structure

The measure structure has been changed to lumen bins, from the wattage bin structure of the previous revision (R3) of the workpaper.

Although the lumen ranges are used on the back-end to match measure case solutions to base case products, as the industry shifts towards LED technologies, referencing solutions by wattages becomes outdated. Older incumbent technologies were referred to by wattages and not light output by the industry because the efficacies (lumens per watt, LPW) of these products were constant within the technology for a given light output and the level of service was understood through the wattage they consumed. With LEDs, products that provide a given light output are available along the entire efficacy & wattage spectrum.

When comparing an equivalent measure case product to the base case, using lumens is much more straightforward. Customers now speak about LED products’ level of service in terms of lumens rather than watts. To match this shift in technology and industry communication & make it easier for customers to choose the right measure, PG&E proposes changing the workpaper measure structure to lumen bins rather than wattage bins.

The challenges with the wattage range methodology as the technology shifts to LED is further explained in the 2015 California Workpaper Update Study conducted by Navigant:10

*“The original CA lighting disposition used the baseline wattages to bin lighting fixture categories. This technique is effective for capturing the baseline of older technologies, especially considering the explicit goal of determining what efficient wattage will replace the existing inefficient wattage. This follows the logic of a wattage range calculation, the goal being to determine the difference between the initial and final wattage.*

*In practice, the initial wattages of the bay fixtures existed over a wide range of values but the LED responses were contained in a small range. This aspect makes it difficult to create wattage bins based on LED alternatives. It is not possible to accurately measure the savings of a certain LED replacement if it could be replacing a wide range of baseline fixtures.”*

The benefit of the lumen bin methodology is illustrated below. When comparing Tier 1 measure codes to Tier 2 measure codes, it is immediately obvious that a product in the 5,400 – 6,499 lumen range within the Tier 1 efficacy range of 110 – 129 LPW provides equivalent service to a product in the same lumen range with Tier 2 efficacy of 130+ LPW. Under the wattage bin structure in the current workpaper, it is much less obvious that 48W – 71W Tier 1 products are equivalent to 42W – 60W Tier 2 products.

Table 2 Wattage Bin Method (Previous)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Code | Measure Case Tier | Blended Base Case Watts | Blended Base Case Efficacy | Measure Case Efficacy Floor (LPW) | Measure Case Wattage (min) | Measure Case Wattage (max) | Measure Case Lumens (min) | Measure Case Lumens (max) |
| LT376 | Tier 1 | 53 | 87 | 110 | 0 | 47.99 | 4500 | 6239 |
| LT377 | Tier 1 | 81 | 93 | 110 | 48.00 | 70.99 | 5280 | 9229 |
| LT385 | Tier 2 | 53 | 87 | 130 | 0 | 41.99 | 4500 | 10400 |
| LT386 | Tier 2 | 81 | 93 | 130 | 42.00 | 59.99 | 5460 | 14500 |

Table 3 Lumen Bin Method (Proposed)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Measure Code | Measure Case Tier | Blended Base Case Watts | Blended Base Case Efficacy | Measure Case Efficacy Floor (LPW) | Measure Case Lumens (min) | Measure Case Lumens (max) | Measure Case Wattage (minimum Efficacy, Average Output) |
| LT514 | Tier 1 | 58 | 88 | 110 | 4500 | 5399 | 45 |
| LT515 | Tier 1 | 67 | 88 | 110 | 5400 | 6499 | 54 |
| LT526 | Tier 2 | 58 | 88 | 130 | 4500 | 5399 | 38 |
| LT527 | Tier 2 | 67 | 88 | 130 | 5400 | 6499 | 46 |

A customer looking for an LED product to replace a 3-lamp fluorescent fixture under the measure codes defined by wattage bins in Table 12, must determine equivalent service products by calculating the lumens from the wattage ranges shown for each Tier. In Table 13, with Lumen Bins, they can decide the light output they need and it will match both Tiers similarly.

PG&E would seek to align rebate levels with increasing efficacy levels to encourage the desired outcome that program participants will determine the amount of light they need first, and then compare the options between Tier 1 and Tier 2, potentially selecting Tier 2 products based on higher rebate levels.

**Measure Tiers:** The measures are structured with two tiers.

1. Tier 1 contains lower efficacies floors than Tier 2 to accommodate current projects in the pipeline. The efficacy floor for Tier 1 was derived from the 50th percentile of the Lighting Facts database to represent top half of the market and serves as an eligibility requirement. The measure case efficacy used in the savings calculations is the mid-point between the 50th and 75th percentile: 62.5th percentile.
2. Tier 2 is the goal and focus for Programs to drive higher efficiency products into the market for market transformation. The efficacy floor for Tier 2 is derived from the 75th percentile of the Lighting Facts database and serves as an eligibility requirement. The measure case efficacy used in the savings calculations is the mid-point between the 75th and 100th percentile: 87.5th percentile.

**Delta Wattage Assumption (ΔW)**

This section describes the method used to match Fluorescent base case fixtures to equivalent LED fixtures, as done in the previous interim solution. The LED fixtures being matched include both base case and measure case, and the calculations assume no difference in the light distribution, lumen maintenance, or fixture efficiency between the base and measure case LEDs. This is a particularly conservative approach to light distribution of base case TLED products, which tend to put out most of their light between 0 - 60° and are not typically well-configured to produce light at 60 - 80°. However, as no good model for typical base case TLED light distribution exists, they are assumed equivalent to LED fixtures in distribution in this workpaper.

The workpaper assumes 1-to-1 equivalence of maintained Zonal Lumens for each lumen bin. For lumen bin, the closest equivalent in fluorescent lamp quantity and MH lamp wattage are determined, accounting for Zonal Lumens, Lumen Maintenance, and Fixture Efficiency.

The LED measure case wattage values are determined by dividing the midpoint value of the lumen bins by the 120 lm/W minimum efficacy. The base case blended wattage is the blended weighted average of base case LED, TLED, MH, and Fluorescent wattages. Delta watts are the difference between the base case blended wattages and the measure case wattages.

Table 14 LED High-Bay and Low-Bay Fixtures Base and Measure Wattages

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Code** | **Base Case**  **Blended Wattage** | **Measure Case Wattage** | **Delta Watts** |
| LT514 | 58.4 | 45.0 | 13.4 |
| LT515 | 67.4 | 54.1 | 13.3 |
| LT516 | 75.3 | 65.0 | 10.4 |
| LT517 | 95.7 | 78.2 | 17.6 |
| LT518 | 119.4 | 96.4 | 23.0 |
| LT519 | 136.3 | 120.9 | 15.4 |
| LT520 | 168.7 | 138.7 | 29.9 |
| LT521 | 199.0 | 173.3 | 25.6 |
| LT522 | 244.7 | 212.4 | 32.3 |
| LT523 | 303.0 | 276.0 | 27.0 |
| LT524 | 406.6 | 358.8 | 47.8 |
| LT525 | 525.7 | 466.4 | 59.3 |
| LT526 | 58.4 | 38.1 | 20.3 |
| LT527 | 67.4 | 45.8 | 21.6 |
| LT528 | 75.3 | 55.0 | 20.4 |
| LT529 | 95.7 | 66.2 | 29.6 |
| LT530 | 119.4 | 81.5 | 37.8 |
| LT531 | 136.3 | 102.3 | 34.0 |
| LT532 | 168.7 | 128.1 | 40.6 |
| LT533 | 199.0 | 160.0 | 39.0 |
| LT534 | 244.7 | 196.7 | 48.1 |
| LT535 | 303.0 | 255.6 | 47.4 |
| LT536 | 406.6 | 332.2 | 74.4 |
| LT537 | 525.7 | 431.8 | 93.8 |

**Calculation Method Process for Defining Measures**

The zonal lumen percentage is the share of lumens in the 20-50 degree zone from nadir compared to the total lumen output of the fixture. For LEDs (including TLEDs), this was calculated using an average of all of the DLC QPL entries; the value is 53.6%. For Fluorescents, the Zonal Lumens, fixture efficiency, and other performance metrics were calculated from a sample of high bay fixtures, with the results shown in the table below.

Table 5 Example Calculation of Fixture Efficiency and Fixture Lumens

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Fluorescent Fixture Efficiency** | **Ballast Factor** | **T8 Lamp Lumens** | **Zonal Lumen Percentage** | **Fixture Lumens** |
| Fluorescent | 89% | 1.15 | 2957 | 44.7% | 5,286 |

1. To calculate the equivalent total lumens of service for LED, the fluorescent fixture lumens are multiplied by the ratio of fluorescent zonal lumen percentage to LED zonal lumen percentage.

Table Equivalent LED Lumen Output for Similar Levels of Service

|  |  |  |  |
| --- | --- | --- | --- |
| **Fluor ZL %** | **LED ZL %** | **LED Lumens** | **Rounded lumen bin value** |
| 44.71% | 53.6% | 4407.4 | 4500 |

Note: For the lumen bin calculations, see the savings calculation spreadsheet that accompanies this workpaper.

## 2.1 Electric Energy Savings Estimation Methodologies

The electric demand difference is the delta watts (**∆**Watts/fixture) between the electric demand of the base case fixture and the electric demand of the measure case fixture (average wattage of the measure wattage range). Annual energy savings is obtained by taking the delta watts and multiplying by the annual hours of operation. Annual Energy savings vary by market sector (building type) because of differences in operating hours and interactive effect multipliers. The annual operating hours and energy interactive effects for each segment were taken from DEER 2016 data.



***Annual Energy Savings:***



**Example**:

The following example calculation demonstrates the annual electric energy savings in kWh, for the Manufacturing building type for the “LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW” measure:

For the savings of all other measures, see the calculation spreadsheet that accompanies this report.

## 2.2 Demand Reduction Estimation Methodologies

Demand reduction varies by market sector (building type) due to different HVAC interactive effects and coincident peak demand multipliers for each type of building type. The demand interactive effects, and coincident diversity factors (CDF) for each segment were taken from DEER 2016 data.

***Demand Reduction:***



**Example:** The following example calculation demonstrates the peak demand reduction, kW, for the Manufacturing building type, for the “LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW” measure:

For the savings of all other measures, see the calculation spreadsheet that accompanies this report.

## 2.3 Gas Energy Savings Estimation Methodologies

Gas estimates are entirely based on the estimated increased gas use through calculated interactive effects. This measure includes HVAC interactive effects impacts.

**∆Watts/fixture:** The demand difference (watts per fixture) is simply the difference between the electric demand of the base case fixture and the electric demand of the measure case fixture.

∆Watts/fixture = Base Case Watts/fixture - Measure Case Watts/fixture

***Annual Gas Savings:***



**Example**:

The following example calculation demonstrates the annual gas savings in therms, for the Manufacturing building type for the “LED HighBay luminaire rated from 5400 to < 6500 lumens and >= 130 LPW” measure:

For the savings of all other measures, see the calculation spreadsheet that accompanies this report.

# 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 non-residential 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 the KEMA report [31] for a more thorough discussion regarding the load shapes for this

measure.

# Section 4 Base Case & Measure Costs

DEER 2016 does not have measure cost data for LED fixtures.

The following data sources were used to develop the base case and measure costs:

1. PG&E Program Data
2. SCE Program Data
3. TRC Cost Study Data
4. Online pricing (Web-scraping)

## 4.1 Base Case Costs

It is assumed the labor cost of replacing the measure case fixture would be the same as the base case fixture. The base case and measure case costs include just equipment costs. The base case costs are taken from distributor catalogs and websites and confirmed with manufacturer representatives where possible.

**Linear Fluorescent:** Costs for linear fluorescent came from online fixture vendors, and labor costs were calculated using WO017[[19]](#endnote-20). The labor cost used was $187.14.

**LED:** Costs for base case and measure case LED came from the average of 4 data sources:

1. PG&E Program Data
2. SCE Program Data
3. TRC Cost Study Data
4. Online pricing (Web-scraping)

**TLED:** Costs for base case TLED came from online pricing via web-scraping. Because TLEDs vary widely in wattage, price, and light output, the prices were normalized by light output at the midpoint of the lumen bin. Based on the February 2019 web-scraped cost data the average TLED price was $9.23 with an average light output of 2,582 lumens, which yields a cost of $0.0036 per lumen. See attached file “Copy of TLED Cost Data\_FEB2019.xlsx” for details of the cost data and the calculations.

## 4.2 Measure Case Costs

The measure equipment costs were developed from California distributor catalogs and websites and confirmed with manufacturer representatives where possible.

Labor costs were calculated using WO017[[20]](#endnote-21). The labor cost used was $187.14. The labor cost is assumed to be the same as the base case labor cost.

**LED:** Costs for base case and measure case LED came from the average of 4 data sources:

1. PG&E Program Data
2. SCE Program Data
3. TRC Cost Study Data
4. Online pricing

## 

## 4.3 Incremental & Full Measure Costs

Table Incremental and Full Measure Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |
| RET/ER | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REF | (MEC + MLC) – (BEC + BLC) | MEC + MLC | N/A |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Please refer to the savings spreadsheet for detailed base case and measure case cost information.

### 4.3.1 Full Measure Cost

The Full Measure Cost is applicable to Direct Install programs. There is an effort on updating systems to collect actual costs from implementers. Until then the measure equipment costs plus the labor cost of $187.14 will be used for direct install.

FMC = Measure Equipment Cost + Measure Labor Cost

# Attachments

Attachment 1 – ROB vs NC.xlsx

Attachment 2 – ProgramCostData2016.01.01-2018.03.29\_cleaned.xlsx

Attachment 3 – SCE High Bay Pricing.xlsx

Attachment 4 – LF\_Efficacy and Output\_20180525.xlsx

Attachment 5 - HighLowBay-InterimSolution\_20180525.xlsx

PGECOLTG178 R4 EDReports.xlsx

References

1. National Electrical Manufacturers Association (NEMA) 2Q 2017 Sales Data <https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-to-Decline-in-Second-Quarter-2017-while-T-LED-Market-Penetration-Increases.aspx> [↑](#endnote-ref-2)
2. Navigant Consulting, [California LED Pricing Analysis, January 2018](http://calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_FinalES.pdf) [↑](#endnote-ref-3)
3. <https://www.designlights.org/default/assets/File/Workplan/DLC_Technical-Requirements-Table-V4-4.pdf> [↑](#endnote-ref-4)
4. https://www.designlights.org/search/ [↑](#endnote-ref-5)
5. [https://www.designlights.org/default/assets/File/Workplan/DLC\_Technical-Requirements-Table-V4-4.pdf](https://www.designlights.org/default/assets/File/Workplan/DLC_Technica-Requirements-Table-V4-4.pdf) [↑](#endnote-ref-6)
6. CALiPER Snapshot Industrial Luminaires. DOE. March 13, 2017. <https://www.energy.gov/sites/prod/files/2017/04/f34/snapshot2017_industrial.pdf> [↑](#endnote-ref-7)
7. The table “Measure Application Type” in the Measure Catalog can be found on the Database for Energy-Efficient Resources (DEER) website, <http://www.deeresources.com/> [↑](#endnote-ref-8)
8. <http://www.energy.ca.gov/2017publications/CEC-400-2017-002/CEC-400-2017-002.pdf> [↑](#endnote-ref-9)
9. <http://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf> [↑](#endnote-ref-10)
10. Navigant. California LED Pricing Analysis – Final Report. January 2018.

    <http://www.calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_Final.pdf> [↑](#endnote-ref-11)
11. Navigant. California LED Workpaper Update Study – Final Report. August 28, 2015. <http://www.calmac.org/publications/LED_Study_Report_FINAL_201510029.pdf> [↑](#endnote-ref-12)
12. NEMA Linear lamp index, Q2 2017. Accessed at <https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-to-Decline-in-Second-Quarter-2017-while-T-LED-Market-Penetration-Increases.aspx> [↑](#endnote-ref-13)
13. [2016 Non-Residential Lighting Market Characterization, Bonneville Power Administration, July 2017](https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2017_NonResidential_Lighting_Final_Report.pdf) [↑](#endnote-ref-14)
14. [2016 Non-Residential Lighting Market Characterization, Bonneville Power Administration, July 2017](https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2017_NonResidential_Lighting_Final_Report.pdf) [↑](#endnote-ref-15)
15. Meeting Notes\_04042018\_CS EAR and PGE\_Lighting Workpapers Status Update & Meeting Notes\_04052018\_CS EAR and PGE\_Lighting Workpapers Status Update [↑](#endnote-ref-16)
16. Meeting Notes\_04042018\_CS EAR and PGE\_Lighting Workpapers Status Update & Meeting Notes\_04052018\_CS EAR and PGE\_Lighting Workpapers Status Update [↑](#endnote-ref-17)
17. CALiPER Snapshot Report Linear Lamps (TLEDs), June 17, 2017. Accessed at <https://www.energy.gov/sites/prod/files/2016/07/f33/snapshot2016_tleds.pdf> [↑](#endnote-ref-18)
18. CALiPER Summary Report Round 13. DOE. October 2011. <https://www.energy.gov/eere/ssl/caliper-report-archives> [↑](#endnote-ref-19)
19. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014. Table 4-6. Page 4-12. *HID to T5 Fixtures high bay, lift accessible.* [↑](#endnote-ref-20)
20. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014. Table 4-6. Page 4-12. *HID to T5 Fixtures high bay, lift accessible.* [↑](#endnote-ref-21)