**Work Paper PGECOLTG179**

**LED Ambient Commercial Fixtures and Retrofit Kits**

**Revision # 6**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**LED Ambient Commercial Fixtures and Retrofit Kits**

**Measure Codes LT488 – LT499; LT502-LT513**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LT488– LT499; LT502-LT513 |
| **Measure Description:** | LED Luminaires/Retrofit Kits rated ≥125 LPW, Linear Ambient and Troffer General Applications |
| **Energy Impact Common Units:** | Kilolumen of LED initial light output |
| **Base Case Description:** | 67% new 100 lm/W LED fixture or retrofit kit; 33% linear LED replacement lamp (TLED) in existing fluorescent fixture.  Source: PG&E Calculations. |
| **Base Case Energy Consumption:** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: PG&E Calculations. |
| **Measure Energy Consumption:** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: PG&E Calculations. |
| **Energy Savings**  **(Base Case – Measure):** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: PG&E Calculations. |
| **Costs Common Units:** | $ per kilolumen. |
| **Base Case Equipment Cost ($/kilolumen):** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx” and “Copy of TLED Cost Data\_FEB2019.xlsx”.  Source: Distributor Quotations and online web-scraping |
| **Measure Equipment Cost ($/kilolumen):** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: Manufacturer Rep and Distributor Quotations and web-scraping |
| **Gross Measure Cost ($/kilolumen)** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: Manufacturer Rep and Distributor Quotations and web-scraping |
| **Measure Incremental Cost ($/kilolumen):** | Various.  Refer to “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”  Source: PG&E Calculations |
| **Effective Useful Life (years):** | 16 years, ILtg-Com-LED-50000hr+16yr  16 years, ILtg-Res-LED-50000hr+16yr  Source: DEER2016 |
| **Program Type:** | NR (Normal Replacement) |
| **Net-to-Gross Ratios:** | NTG = 0.91 per Resolution E-4952 |
| **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 | 2/25/2015 | PGECOLTG179 R0 LED Ambient Commercial Fixtures and Retrofit Kits.doc  Original Workpaper | Author: Greg Barker (Energy Solutions)  Reviewer: Alina Zohrabian (PG&E) |
| Revision 1 | 1/1/2016 | Added upstream delivery channel. Updated NTG & EUL IDs per DEER2016. | Alina Zohrabian (PG&E) |
| Revision 2 | 6/1/2016 | Added DLC Premium Tier requirement for transition on July 15,2016; removed 12 measure codes that fall below DLC Premium efficacy. Updated costs based on recent cost data. No changes in savings, EUL, NTG. | Author: Greg Barker (Energy Solutions)  Reviewer: Alina Zohrabian (PG&E) |
| Revision 3 | 11/28/2016 | Updated Residential Interactive Effect(IE) factors per DEER 2017; The ET\_NTG expired so the Direct Install NTG changes from 0.85 to 0.7 | Mini Damodaran (PG&E)/ Alina Zohrabian (PG&E) |
| Revision 4 | 6/28/2017 | -NTG values changed from All-Default<=2yrs =0.7 to Com-Default>2yrs = 0.6 for Commercial and Res-Default>2 =0.55 for Residential sector effective 10/1/2017 | Mini Damodaran (PG&E) |
| Revision 5 | 7/12/2017 | -Updated to DLC Technical Requirements v4.2  -Updated costs; Measure codes to be -Retired as of 12/31/2017 are LT042, LT043 LT046, LT047, LT050, LT051, LT054, LT055, LT058, LT059, LT062, LT063  -New measure codes LT148-LT159 added and will be effective 1/1/2018 | Greg Barker (Energy Solutions)/ Mini Damodaran (PG&E) |
| Revision 6 | 12/10/2018  3/1/2019 | Per Resolution E-4952, base case set to 100% LED technology based on 25th percentile of Lighting Facts and minimum efficacy of 100 LPW, and updated the NTG value to 0.91. Incorporated TLED into the base case cost and savings calculations. Added linear LED ambient lights. Removed NC MAT. This revision to be effective 4/1/2019.  Revised TLED 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](#_Toc2808631)

[Document Revision History iv](#_Toc2808632)

[List of Tables vi](#_Toc2808633)

[List of Figures vi](#_Toc2808634)

[Section 1. General Measure & Baseline Data 1](#_Toc2808635)

[1.1 Background 1](#_Toc2808636)

[1.2 Product Measure Description 1](#_Toc2808637)

[1.3 Product Technical Description 5](#_Toc2808638)

[1.4 Installation Types & Delivery Mechanisms 5](#_Toc2808639)

[1.5 Product Base Case and Measure Case Data 6](#_Toc2808640)

[1.5.1 DEER Data 6](#_Toc2808641)

[1.5.2 Codes & Standards and Standard Practice (SP) Baseline and Measure Information 8](#_Toc2808642)

[1.5.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 8](#_Toc2808643)

[1.5.4 Assumptions and Calculations from other sources – Base and Measure Cases 15](#_Toc2808644)

[Section 2. Calculation Methods 16](#_Toc2808645)

[2.1 Electric Energy Savings Estimation Methodologies 16](#_Toc2808646)

[2.2. Demand Reduction Estimation Methodologies 17](#_Toc2808647)

[2.3. Gas Energy Savings Estimation Methodologies 17](#_Toc2808648)

[Section 3. Load Shapes 18](#_Toc2808649)

[3.1 Base Case Load Shapes 18](#_Toc2808650)

[3.2 Measure Load Shapes 18](#_Toc2808651)

[Section 4. Base Case & Measure Costs 19](#_Toc2808652)

[4.1 Base Case Costs 19](#_Toc2808653)

[4.2 Measure Costs 19](#_Toc2808654)

[4.3 Incremental & Full Measure Costs 20](#_Toc2808655)

[4.3.1 Full Measure Cost 20](#_Toc2808656)

[4.3.2 Incremental Measure Costs 21](#_Toc2808657)

[References: 22](#_Toc2808658)

# List of Tables

[Table 1: LED Ambient Fixtures & Retrofit Kits Minimum Measure Efficacies 2](#_Toc2791455)

[Table 2: Measure Application Type 5](#_Toc2791456)

[Table 3: Delivery Method and Applicable Building Types 6](#_Toc2791457)

[Table 4: DEER Differences Summary 7](#_Toc2791458)

[Table 5: Installation Rate 7](#_Toc2791459)

[Table 6: LED Ambient Fixtures & Retrofit Kits Base and Measure Wattages 16](#_Toc2791460)

[Table 7: LED Ambient Fixtures & Retrofit Kits Base Case Cost Table 19](#_Toc2791461)

[Table 8: LED Ambient Fixtures & Retrofit Kits Measure Cost Table 19](#_Toc2791462)

[Table 9: LED Ambient Commercial Fixtures & Retrofit Kits Full Measure Cost 20](#_Toc2791463)

[Table 10: LED Ambient Commercial Fixtures & Retrofit Kits Incremental Cost 21](#_Toc2791464)

# List of Figures

[Figure 1: Web-based LED Price and Efficacy Data for Recessed Troffer/Panel 2’ x 4’ 9](#_Toc2791465)

[Figure 2: NEMA Linear Lamp Penetration, Q2 2017 11](#_Toc2791466)

[Figure 3: Impact of TLEDs on IMC for LED Troffer measures 12](#_Toc2791467)

[Figure 4: Proposed workpaper methodology adding TLEDs to baseline 13](#_Toc2791468)

# Section 1. General Measure & Baseline Data

## 1.1 Background

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 all LEDs (or a significant fraction of LEDs) 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.

In late 2018 the Resolution E-4952 directed DEER2019 update to incorporate the standard practice baselines from the recent dispositions covering exterior, interior low-bay, interior high-bay, screw-in and can-retrofit lighting. In addition to incorporating measures covered by recent workpaper dispositions, DEER2019 also updates the standard practice baseline for all other interior lighting NR, NC, and AR measures to be based on LED technologies. This includes LED ceiling, troffer and retrofit kits measures that have previously been defined with T8 linear fluorescent baselines. Thus PG&E’s workpaper “PGECOLTG179 LED Ambient Commercial Fixtures and Retrofit Kits” is affected by this standard practice baseline.

PG&E’s early 2018 research and communications with the CPUC Ex-Ante Review (EAR) Team noted challenges with negative IMC values as baseline technologies shift to LED - the same technology as the measure case. In conversations with the EAR Team in April of 2018 during development of the interim solution for LED High-Bay and Low-Bay workpaper, the EAR Team acknowledged linear LED lamps’ (TLEDs) popularity in the market and alluded that PG&E could consider adding TLEDs to the baseline mix for fixtures that have had fluorescent T8s in their baseline history. Based on these discussions and additional research, PG&E incorporated TLEDs to the baseline LED technology for this workpaper revision.

CPUC Ex-Ante team recommendation: PG&E has provided TLED costs and efficacy data collected in 2018 for the initial R4 workpaper revision. Subsequently PG&E conducted additional online web-scraping on TLED costs and efficacy in February 2019 per CPUC Ex-Ante 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 costs and efficacy.

## 1.2 Product Measure Description

***Catalog Description***

Light Emitting Diode (LED) Ambient and Troffer Fixtures and Retrofit Kits

**Requirements:**

* New LED luminaire must have rated lumen output similar to the rated lumen output of the fixture being replaced or retrofitted
* Must be a DesignLights Consortium® (DLC) approved New Luminaire, Integrated Retrofit Kit, or Direct Linear Ambient Fixture or Retrofit Kit listed as:
  + Luminaires/Integrated Retrofit Kits for Ambient Lighting of Interior Commercial Spaces in one of the following sizes: 2x4, 2x2, 1x4
  + Linear Ambient Luminaires/Retrofit Kits for Direct Linear Ambient Luminaires in one of the following sizes: 2’ Linear, 4’ Linear, 8’ Linear
* Must be listed as DLC Premium
* Linear LED replacement lamps (TLED) do not qualify
* Self-ballasted or screw-based lamps do not qualify.
* 5-year warranty minimum
* Must meet the minimum efficacy requirements listed in Table 1 effective April 1, 2019.

**For Troffer products:**

* DLC-listed initial light output must be ≥ 2200 lm and ≤ 6500 lm
* Only Fixtures and Retrofit kits that include new lenses between the LED package and the viewer qualify.

**For Linear Ambient products only:**

* DLC-listed initial light output must be ≤ 6,500 lm

Table 1: LED Ambient Fixtures & Retrofit Kits Minimum Measure Efficacies

|  |  |
| --- | --- |
| **Measure Code** | **Measure description** |
| LT488 | 2x4 LED new Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT489 | 2x4 LED new Luminaire rated greater than or equal to 140 LPW |
| LT490 | 2x2 LED new Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT491 | 2x2 LED new Luminaire rated greater than or equal to 140 LPW |
| LT492 | 1x4 LED new Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT493 | 1x4 LED new Luminaire rated greater than or equal to 140 LPW |
| LT494 | 2x4 LED Integrated retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT495 | 2x4 LED Integrated retrofit kit rated greater than or equal to 140 LPW |
| LT496 | 2x2 LED Integrated retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT497 | 2x2 LED Integrated retrofit kit rated greater than or equal to 140 LPW |
| LT498 | 1x4 LED Integrated retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT499 | 1x4 LED Integrated retrofit kit rated greater than or equal to 140 LPW |
| LT512 | LED Direct or Indirect Linear Ambient 2' New Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT513 | LED Direct or Indirect Linear Ambient 2' New Luminaire rated greater than or equal to 140 LPW |
| LT502 | LED Direct or Indirect Linear Ambient 4' New Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT503 | LED Direct or Indirect Linear Ambient 4' New Luminaire rated greater than or equal to 140 LPW |
| LT504 | LED Direct or Indirect Linear Ambient 8' New Luminaire rated greater than or equal to 125 LPW and less than 140 LPW |
| LT505 | LED Direct or Indirect Linear Ambient 8' New Luminaire rated greater than or equal to 140 LPW |
| LT506 | LED Direct Linear Ambient 2' retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT507 | LED Direct Linear Ambient 2' retrofit kit rated greater than or equal to 140 LPW |
| LT508 | LED Direct Linear Ambient 4' retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT509 | LED Direct Linear Ambient 4' retrofit kit rated greater than or equal to 140 LPW |
| LT510 | LED Direct Linear Ambient 8' retrofit kit rated greater than or equal to 125 LPW and less than 140 LPW |
| LT511 | LED Direct Linear Ambient 8' retrofit kit rated greater than or equal to 140 LPW |

**Exclusions:**

* Fixtures listed under specialty primary uses on the DLC QPL do not qualify for these deemed measures.
* Other fixture configurations, including LED troffer linear retrofit kits or external driver lamp-style retrofit kits (Underwriters Laboratories, Type C) do not qualify for this rebate. These configurations will be considered under the Customized Retrofit Program.
* Exterior or high/low-bay installations of these products do not qualify for this rebate.
* Products in the above listed categories, less than 2,200 lm or greater than 6,500 lm, do not qualify for this rebate and will be considered under the Customized Retrofit Program.
* Screw-based lamps and linear replacement lamps do not qualify.
* Must meet the minimum efficacy range listed for the appropriate measure codes in Table 1.

**Additional Details:**

* Customer selects the measure code based on the efficacy in lumens per watt (LPW) of the replacement fixture.
* LED Troffer and Integrated Troffer Retrofit rebates are offered on a per kilolumen (KLM)—1,000 lumens—basis, rather than a per fixture basis. The rebate increases as the efficacy (LPW) of the fixture or retrofit kit increases.
* Efficacy is defined by LPW, or how much light is produced by one watt of energy consumed.
* A lumen is the unit of light output: kilolumen = 1,000 lumens.

***Program Restrictions and Guidelines***

This workpaper details the replacement of linear ambient fixtures, retrofit kits, and linear LED replacement lamps in fixtures with higher efficacy LED ambient fixtures, integrated retrofit kits, and direct linear ambient retrofit kits. The workpaper offers delivery methods for non-residential customers through Upstream/Midstream, Downstream, or Direct Install Deemed programs.

DLC requirements for Indoor Ambient Lighting Products include

* 5-year warranty
* 50,000 hour L70 Lumen Maintenance
* 36,000 hour L90 Lumen Maintenance
* ≥ 80 Color Rendering Index (CRI)
* **≥ 125 lumens per watt (PG&E Requirement)**
* ≤ 5000 Kelvin Correlated Color Temperature (CCT)

DLC requirements for Integrated Retrofit Kits and Luminaires for Ambient Lighting of Interior Commercial Spaces (2x4, 2x2, 1x4) include:

* Spacing Criteria from 1.0 to 2.0 in both the 0-180° and 90-270° directions
* ≥75% of Lumen Output in the 0-60° zone

DLC requirement for Direct Linear Ambient luminaires and retrofit kits:

* ≥40% of Lumen Output in the 0-60° zone
* ≥35% of Lumen Output in the 90-150° zone

|  |
| --- |
| **DLC Categories Eligible under this Workpaper:** |
| * Must be in one of nine DLC product categories:   + 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces   + Integrated Retrofit Kits for 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces   + 2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces   + Integrated Retrofit Kits for 2x2 Luminaires for Ambient Lighting of Interior Commercial Spaces   + 1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces   + Integrated Retrofit Kits for 1x4 Luminaires for Ambient Lighting of Interior Commercial Spaces   + Direct Linear Ambient Luminaires   + Linear Ambient Luminaires with Indirect Component   + Retrofit Kits for Direct Linear Ambient Luminaires |

Products must meet exact technical requirements listed on DLC for these product categories stated above.

**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.

## 1.3 Product Technical Description

Light emitting diode (LED) sources have improved over the past decade making them an efficient and reliable lighting technology. Many LED products have successfully replaced other lighting sources in some applications and made their way into the market through continuous improvement and compete with more established sources across many applications.

Recessed rectangular light fixtures, sometimes known as troffers, have traditionally used linear fluorescent light sources: Predominately T8 lamps with small T5 market share, and a diminishing T12 presence in non-residential building stock. Similar fixture shapes are in use for much less common surface mountings in non-residential buildings, for spaces where recessed ceiling space is unavailable but ease of maintenance dictates a common lamp type. 4 foot lamps predominate, with 2 foot or U-bent lamps common in 2x2 fixtures.

Linear Ambient fixtures have a wide array of uses in non-residential applications. These fixtures are used for Direct and Indirect lighting in office and retail environments, industrial and warehouse linear lighting, ingress-protected linear lighting, and other uses. Lighting for these applications has been traditionally provided by various forms of linear fluorescent fixtures that span a wide range of aesthetic quality from Class A office space to industrial work space to retail stockroom: fluorescent strips, fluorescent wraps, fluorescent suspended fixtures, and fluorescent vapor-tight fixtures.

LED products offer advantages over linear fluorescent products for the general commercial fixture market. LED chip efficacies now routinely surpass the best fluorescent lamp-and-ballast system efficacies, and the superior directional light control of LEDs allows even greater fixture efficacy improvements. LED products reduce maintenance costs relative to linear fluorescent products that require re-lamping. Linear fluorescent lighting represents 66% of lighting energy use in the commercial and industrial sectors and 78% of all commercial and 90% of all industrial light fixtures, and therefore represents an enormous opportunity for potential LED savings.[[1]](#endnote-1)

LED Ambient Commercial products, which are most commonly offered as recessed, surface-mounted, or suspended fixtures, are available both as complete new fixtures (a.k.a. luminaires) and as integrated retrofit kits. Both options include new LED chips, an LED driver or power supply, and optical control or lenses. Retrofit kits allow these components to be fit into existing linear fluorescent metal housing, whereas new LED luminaires are sold complete with a new metal housing.

Two Emerging Technologies reports commissioned by PG&E’s ET Program have demonstrated savings potential from these measures and allowed PG&E to refine the requirements and specifications for these measures: ET12PGE1481 and ET11PGE3251.[[2]](#endnote-2)

Improvements in LED technology, particularly improving efficacies able to compete with and exceed the best T8 lamp-and-ballast systems producing over 95 lumens per Watt, have made high-performance LED fixtures available for Troffer and Linear Ambient applications.

## 1.4 Installation Types & 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 2: Measure Application Type

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| NR | Normal Replacement | *Measure technology applied instead of Code/Standard technology at the time of replacement, Single baseline (above code), incremental or full costs* |

The measure application type in this workpaper R6 is identified as NR or “Normal Replacement.”

The workpaper supports Programs with midstream, downstream, or direct install delivery channels with normal replacement application types.

Table 3: Delivery Method and Applicable Building Types

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

## 1.5 Product Base Case and Measure Case Data

Eligible measure case fixtures for these measure codes are LED luminaires and LED retrofit kits in Troffer or Linear Ambient Categories with efficacy ≥125 LPW. Troffer eligibility is limited to products with initial light output between 2,200 and 6,500 lumens, and Linear Ambient eligibility is limited to products with initial light output below 6,500 lumens.

Per Resolution E-4952 the appropriate base case fixtures and retrofit kits are LED technology of 100 lumens per watt (LPW) efficacy, approximately equal to the 25th percentile efficacy of the LED fixture performance range. New fixtures and luminaires compose 67% of the base case. This workpaper revision introduces linear LED replacement lamps (TLEDs) as the remaining 33% of the base case, with the bare-lamp TLED efficacy set at the same benchmark as luminaire and retrofit kit performance, the 25th percentile efficacy of the TLED performance range. Evidence from SCE & PG&E participation data, input from local distribution channels, and the California LED Pricing Analysis Study by Navigant all suggest that TLEDS are a viable and commonly-used retrofit alternative to full fixture replacements, while the National Electrical Manufacturers Association’s (NEMA’s) national sales data shows that TLED market penetration has been steadily increasing. Supporting data on TLED market share and purchase scenarios are presented below in 1.5.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information, including BPA’s study indicating the popularity of TLEDs.

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.

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 DOE

Energy consumption is calculated based on a mix of 33% TLED and 67% LED new luminaire or full retrofit kit. The base case wattage per kilolumen is a blend of 85.2 lm/W for TLEDs and 100 LPW for new luminaires and retrofit kits, or 95 LPW overall.

### 1.5.1 DEER Data

The Database for Energy Efficient Resources (DEER) 2016 does not address LED savings for panel fixtures and retrofit kits.

This revision R9 of the workpaper is an update to the current revision R8 now found in the Database for Energy Efficient Resources (DEER).

Table 4: DEER Differences 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 |
| DEER Measure IDs Used | Propose new |

**Net-to-Gross Ratio**

Per Resolution E-4952, section 4.5 Net-to-Gross for Lighting Measures:

“As discussed in Section [4.2,](#_bookmark37) DEER updates and several workpaper dispositions have updated the code and standard practice baselines for lighting measures to include all or a significant fraction of LEDs. Prior to the DEER2019/2020 update, these updates have covered screw-in lamps, exterior lighting fixtures, interior high-bay fixtures and interior low-bay fixtures. At this time, other fixtures such as linear fluorescent retrofit kits, ceiling mounted LED fixtures and ceiling grid fixtures have savings estimates based on linear fluorescent code or standard practice baselines. This DEER version updates, effective January 1, 2019, baselines for these remaining lighting fixture types to be entirely LED technologies. With this change, it is reasonable to raise the NTG value for these measures to 0.91, which is the same value directed by 2018 Phase 1 workpaper dispositions for exterior, interior high-bay and interior low-bay fixtures. This NTG value is allowed for only normal replacement (NR) and new construction (NC) measure application types.”

**Spillage Rate**

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

**Installation Rate**

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

Table 5: Installation Rate

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

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

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)

Hours of Operation by building type are taken from DEER.

### 1.5.2 Codes & Standards and Standard Practice (SP) Baseline and Measure Information

***Federal Standards:*** These LED measure case fixtures do not fall under Federal DOE or EPA Energy Regulations. Both General Service Fluorescent lamps and ballasts are energy-using components of linear fluorescent fixtures and are regulated by Federal Standards.

1. 4-foot medium bi-pin lamps ≤4500K are required to meet 89 LPW (2,848 lm per 32 Watt lamp)[[3]](#endnote-3)
2. Ballasts for 4-foot medium bi-pin lamps are required by EPCA’s 2011 amendment to have a ballast luminous efficacy (BLE) no less than 0.993/(1 + 0.27 ͯ total lamp arc power ^ - 0.25)[[4]](#endnote-4)

For Normal Replacement scenarios, only the ballast performance matters, and only for TLED Type A products. For these products serving 32-Watt 4-foot products, a 90% BLE is assumed, exceeding the 89.2% federal requirement.

***Title 20:*** These measure case fixtures do not fall under Title 20 of the California Energy Regulations

***Title 24:*** The recently adopted 2019 California Title 24 Building Energy Standards reduces interior lighting power allowances based largely on the use of LED technologies.[[5]](#endnote-5)

As part of the 2019 update to Title 24, the IOU’s Codes and Standards indoor Lighting Power Densities study revised lighting power densities for all building and space types. The 2013 Codes and standards Study “Indoor Lighting Controls” assumed the use of high performance lighting technologies including “high performance” linear fluorescent lamps and reduced light output ballasts, the 2019 Study assumes LED technology for all lighting and as a result the proposed lighting power density have been significantly reduced.

**DEER SP Baseline for Lighting**

The DEER2019 update incorporates the standard practice baselines from the recent dispositions covering exterior, interior low-bay, interior high-bay, screw-in and can-retrofit lighting. In addition to incorporating measures covered by recent workpaper dispositions, DEER2019 updates the standard practice baseline for all other NR, NC, ROB and AR measures to be based on LED technologies. This includes LED ceiling, troffer and retrofit kits measures that have previously been defined with T8 linear fluorescent baselines.

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

#### 1.5.3.1 California LED Pricing Analysis, Navigant 2018:[[6]](#endnote-6)

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 troffer 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. 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 is continuing this per-kilolumen measure structure where both costs and savings scale per unit of lumen output, and efficacy is separated by tier.

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



Figure 1: 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, lumen output is a main driver of LED price. 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.

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 linear fluorescent fixtures. This has implications for this workpaper since it currently assumes a fixture-to-fixture comparison between base case and measure case. 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 revision now includes that scenario in the baseline.

The 2018 California LED Pricing Analysis by Navigant distinguishes the lighting luminaire market from the replacement market:

*Navigant evaluated incremental cost both with and without baseline fixture costs, in order to represent two distinct scenarios:*

1. ***Luminaire Market:*** *For the luminaire market incremental cost, the baseline system was assumed to comprise a lamp(s), ballast, reflector/diffusor, and the housing. Pricing for each of these system components was included in the baseline system cost. The incremental cost was then calculated relative to a complete LED luminaire. This scenario represented the new construction market where owners and facility managers are comparing technology options equally. It is important to note that this represents a small proportion of total installations.2*
2. ***Replacement Market:*** *For the replacement market, the baseline system comprised of just a lamp(s) and ballast. The replacement market baseline system does not include reflector/diffusors or housing. This scenario represented the replacement on lamp or ballast burn-out where owners and facility managers are not comparing technology options equally due to the long lifetime of commercial baseline fixtures (above 100,000 hours). This represents a relatively larger proportion of total installations.*3

*Key findings included:*

* *The incremental costs of DLC and ENERGY STAR qualified LED products to complete baseline luminaire systems (lamp(s), ballast, reflector/diffusor and fixture) for certain priority products, particularly in the outdoor groups, were negative. This indicates that LED products were sometimes less expensive than, or comparable to, baseline systems.*
* *However, comparing fixture-to-fixture represents a small proportion of the market, accounting primarily for new construction installations. The replacement market, in which a complete DLC and ENERGY STAR qualified LED product is compared to a baseline lamp(s) and ballast, yields high incremental costs in every product category and represents a more common consumer purchasing scenario.*

Drawing on these results, this workpaper models the base case based on the full market, including the replacement market that Navigant found to be much larger, under the constraint of a 100% LED baseline per Resolution E-4952. As a result, the baseline share of LED tubular replacement lamps (TLEDs) is estimated at a significant share, 33%. The 33% 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.

#### 1.5.3.2 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 alternative to purchase of a 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 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.



Figure 2: 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).[[7]](#endnote-7) 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.

#### 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 (100+ lm/W) or measure case (125+ lm/W) LED products.

Figure 3: 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 High-bays 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.[[8]](#endnote-8) 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 Section 1.5.3.6 LED Non-Residential Lighting Market Characterization, Navigant – In Progress.
* **Statewide Non-Residential Interior Lighting Standard Practices Study:** Launching in March 2019, this study will be conducted by TRC Energy Services to 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

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

For PGECOLTG179, DEER2019 modifies the baseline to 100% LED technologies. PG&E proposes a blend of 33% TLEDs and 67% 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.

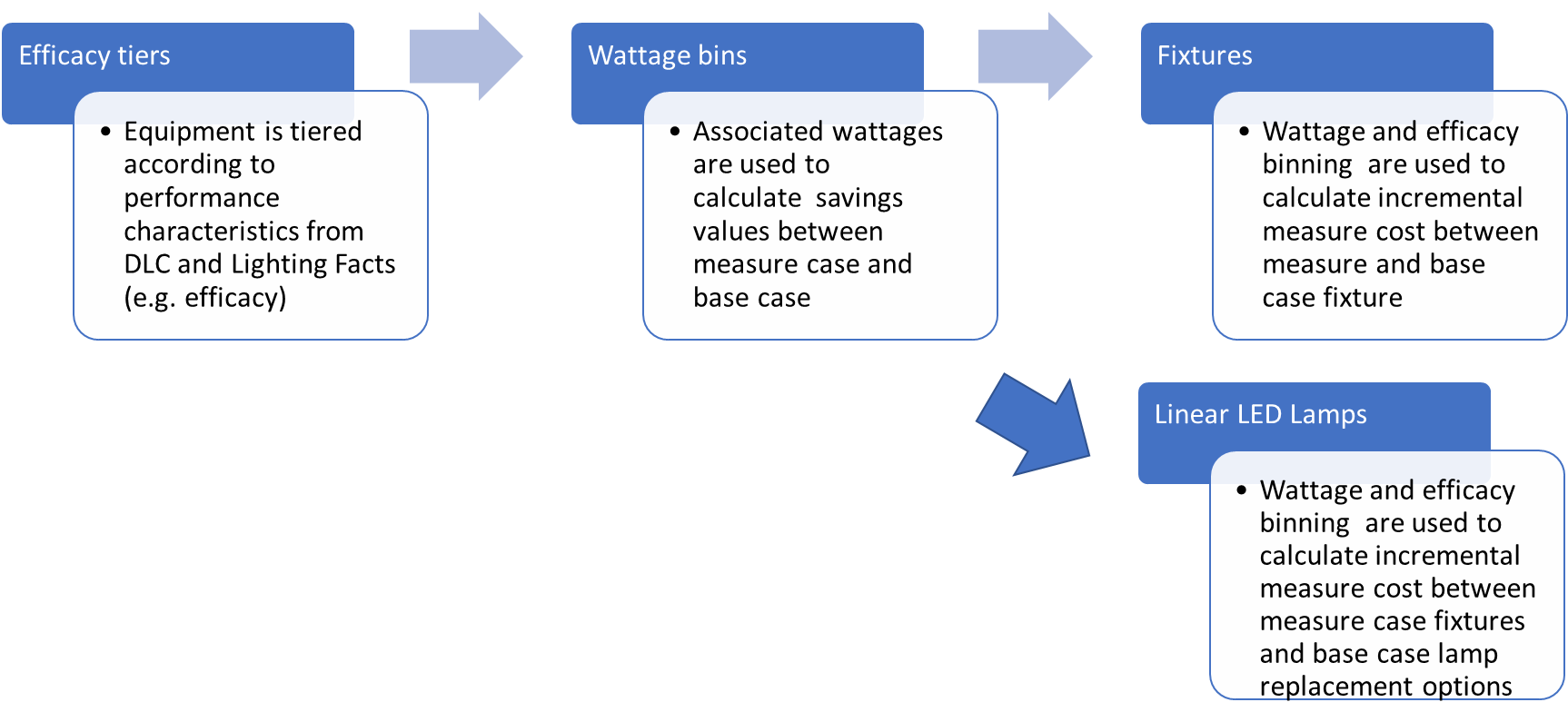


Figure 4: Proposed workpaper methodology adding TLEDs to baseline

#### 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.[[9]](#endnote-9)

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.[[10]](#endnote-10)

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

#### 1.5.3.3 CALiPER Snapshot Report December 7, 2016:[[11]](#endnote-11)

A few of the conclusions that CALiPER reported in its most recent snapshot report on LED Troffers:

* About 10% of the listed products had a luminous efficacy greater than 125 lm/W, so DLC Premium-level products are less than a tenth of the market by this dataset..
* The output of some of the listed LED products exceeds what is typical of a fluorescent troffer, supporting the continuation of an upper lumen output limit for this office/classroom/retail typical measure.

#### 1.5.3.4 CALiPER Snapshot Report June 17, 2016:[[12]](#endnote-12)

A few of the conclusions that CALiPER reported in its most recent snapshot report on TLEDs:

* Over 90% of the currently listed TLEDs exceed 100 LPW, which is roughly the efficacy of a bare linear fluorescent lamp, and near to the qualification threshold for the DesignLights Consortium™ Products List of 110 LPW. 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’s 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 LPW 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 existing fluorescent ballasts, which increases wattage. CALiPER does not address the percentage of TLEDs operating with a fluorescent ballast. 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 QPL 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 efficiency and fixture losses yields an efficacy of 85.2 LPW for TLEDs in fixtures (see attached file “PGECOLTG179 R6 Ambient Ltg Calc\_Mar2019.xlsx”, tab “TLED info” for details of the calculations).

#### 1.5.3.5 Previous CALiPER studies:

Previous DOE Solid-State Lighting CALiPER Reports have examined 12 LED panel fixtures combined in application summary reports 1, 5, 7, 9 and 13, but none of these tests are dated more recently than September of 2011, making them of limited relevance for a workpaper in 2018 given LED improvements. Given their age, earlier CALiPER reports were not used for determining market share, performance, or savings.

#### 1.5.3.6 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 an earlier revision of this workpaper, seeking additional clarification on qualifying LED technologies for the IOUs. Its expected completion date is Q1 2019. 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 QPL. 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 PA’s lighting portfolio. The DLC will also be incorporating a major upgrade to Quality of Light requirements in version 5.0 of its technical requirements.

This study has been expanded to include distributor surveys to determine the standard practice baseline for interior LED categories. These surveys will ask distributors about their current sales/purchase mix by lighting technology, including LEDs. They will ask about the last 12 months and the projected sales mix by lighting technology for each of the next five years. The sales data is being collected separately for each interior product category and also attempts to collect efficacy data within LED products being sold.

Until this study is completed, IOUs will use the DOE Lighting Facts database as a proxy for representing the LED market.

### 1.5.4 Assumptions and Calculations from other sources – Base and Measure Cases

The fixture performance in the applicable General Applications of the DLC list—Troffer Luminaires, Integrated Troffer Retrofit Kits, Linear Ambient Luminaires, Linear Ambient Integrated Retrofit Kits--were analyzed to justify the light output equivalency assumptions. There were 122,217 fixtures in these categories downloaded from DLC in December 2018. These were used to create the 24 measure code tiers with the appropriate luminaire efficacies.

**Delta Wattage Assumption (ΔW)**

The Normal Replacement scenario baseline is 100% LED: 33% TLED and 67% LED new luminaire or retrofit kit. The workpaper assumes no meaningful differences between measure and base cases in lumen depreciation, light distribution, or other factors affecting energy savings. The delta Wattage equation is therefore relatively simple:

Workpaper calculations verify that the luminous efficacies assumed above, both base and measure case, will result in Lighting Power Densities (LPDs) that meet California Title 24-2016 (T24) interior commercial LPD requirements.

# 

# Section 2. Calculation Methods

This workpaper does not group base and measure case fixtures by wattages. The base case and measure wattages are determined by simple division of a kilolumen (1000 lumens) by the efficacy minimums: 125 and 140 LPW for Measure Case, 100 LPW for base case LED Fixtures per Resolution E-4952.

Table 6: LED Ambient Fixtures & Retrofit Kits Base and Measure Wattages

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Case Description** | **Base Case Wattage** | **Measure Case Wattage** | **Delta Wattage** |
| LED Troffer Luminaires/Retrofit Kits rated ≥125 and <140 LPW | 10.6 | 8.0 | 2.6 |
| LED Troffer Luminaires/Retrofit Kits rated ≥140 LPW | 10.6 | 7.1 | 3.4 |
| LED Linear Ambient Luminaires/Retrofit Kits rated ≥125 and <140 LPW | 10.6 | 8.0 | 2.6 |
| LED Linear Ambient Luminaires/Retrofit Kits rated ≥140 LPW | 10.6 | 7.1 | 3.4 |

## 

## 2.1 Electric Energy Savings Estimation Methodologies

The lighting wattage difference (Watts per unit) is the difference between the electric demand of the base case unit and the electric demand of the measure case unit. The operating hours and interactive effects for Commercial were taken from DEER 2016 data. The operating hours and interactive effects for Residential were taken from DEER 2017.

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

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

**Example:**

∆Watts/kilolumen = 10.6 W – 8.0 W = 2.6

**Annual Electric Savings:**

Annual Energy Savings [kWh/kilolumen] = (∆Watts/kilolumen) x (Annual Hours of Operation) x (Energy Interactive Effects) / (1,000 Watts / kW)

## 2.2. Demand Reduction Estimation Methodologies

This measure includes HVAC interactive effects savings. The operating hours and interactive effects for Commercial were taken from DEER 2016 data. The operating hours and interactive effects for Residential were taken from DEER 2017.

**∆Watts/kilolumen:** The demand difference (watts per kilolumen) is simply the difference between the electric demand of a kilolumen unit of the base fixture and the electric demand of a kilolumen unit of the energy efficient fixture.

**∆Watts/kilolumen = Base Watts/kilolumen - Energy Efficient Watts/kilolumen**

**Where:**

Base Case Watts/Kilolumen represents code/industry standard base unit demand.

**Demand Reduction:**

Demand Reduction [kW/kilolumen] = (∆Watts/kilolumen) x (Lighting Coincident Demand) x (Demand Interactive Effects) / (1,000 Watts/kW)

## 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. The operating hours and interactive effects for Commercial were taken from DEER 2016 data. The operating hours and interactive effects for Residential were taken from DEER 2017.

**∆Watts/kilolumen:** The demand difference (watts per kilolumen) is simply the difference between the electric demand of a kilolumen unit of the base fixture and the electric demand of a kilolumen unit of the energy efficient fixture.

**∆Watts/kilolumen = Base Watts/kilolumen - Energy Efficient Watts/kilolumen**

**Annual Gas Savings:**

Annual Gas Savings [∆Therms/kilolumen] = (∆Watts/kilolumen) x (Annual Hours of Operation) x (Gas Interactive Effects (Therms/kwh)) / 1,000 Watts/kW

# 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 “DEER: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 DEER: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.

## 

## 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. All costs are given per kilolumen.

Table 7: LED Ambient Fixtures & Retrofit Kits Base Case Cost Table

|  |  |
| --- | --- |
| **Measure Description** | **Base Case Equipment Cost**  **($/kilolumen)** |
| LED Troffer Luminaires/Retrofit Kits | **$31.78** |
| LED Linear Ambient Luminaires/Retrofit Kits | **$35.91** |
| TLEDs | **$3.60** |
| All LED Troffer Luminaires/Retrofit Kits Measures  (blend including TLEDs) | **$22.48** |
| All LED Linear Ambient Luminaires/Retrofit Kits Measures  (blend including TLEDs) | **$25.24** |

**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 $3.60 per kilolumen. See attached file “Copy of TLED Cost Data\_FEB2019.xlsx” for the cost data and the calculations.

## 

## 4.2 Measure Costs

The measure equipment costs were developed from California distributor catalogs and websites and confirmed with manufacturer representatives where possible. All costs are given per kilolumen.

Table 8: LED Ambient Fixtures & Retrofit Kits Measure Cost Table

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Description** | **Measure Equipment Cost**  **($/kilolumen)** |
| LT488 – LT498 even | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$28.60** |
| LT489 – LT499 odd | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$28.93** |
| LT512; LT502 – LT510 even | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$31.75** |
| LT513; LT503 – LT511 odd | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$33.13** |

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Gross Measure Cost**  **(RUL Period/First Baseline)** | **Gross Measure Cost**  **(EUL-RUL Period/ Second Baseline)** | **Incremental Measure Cost** |
| AR / ER | Measure Equipment Cost  +Measure Labor Cost | (-1)x(Base Equipment Cost  + Base Labor Cost) | Measure Equipment Cost  – Base Case Equipment Cost |
| NR / ROB | Measure Equipment Cost  – Base Case Equipment Cost | N/A | Measure Equipment Cost  – Base Case Equipment Cost |
| NC | Measure Equipment Cost  – Base Case Equipment Cost | N/A | Measure Equipment Cost  – Base Case Equipment Cost |

### 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 following costs will be used for direct install. All costs are given per kilolumen.

FMC = Measure Equipment Cost + Measure Labor Cost

Table 9: LED Ambient Commercial Fixtures & Retrofit Kits Full Measure Cost

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Description** | **Measure Equipment Cost** | **Measure Labor Cost[[13]](#endnote-13)** | **Full**  **Measure Cost** |
| LT488 – LT498 even | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$28.60** | **$20.97** | **$49.57** |
| LT489 – LT499 odd | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$28.93** | **$20.97** | **$49.90** |
| LT512; LT502 – LT510 even | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$31.75** | **$20.97** | **$52.72** |
| LT513; LT503 – LT511 odd | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$33.13** | **$20.97** | **$54.10** |

### 4.3.2 Incremental Measure Costs

The labor costs for measure and base cases are equivalent.

Incremental cost (INCR) = Measure Cost – Base Case Cost

Table 10: LED Ambient Commercial Fixtures & Retrofit Kits Incremental Cost

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Description** | **Blended Base Cost** | **Measure Cost** | **Incremental Measure Cost** |
| LT488 – LT498 even | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$22.52** | **$28.60** | **$6.08** |
| LT489 – LT499 odd | LED troffer new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$22.52** | **$28.93** | **$6.41** |
| LT512; LT502 – LT510 even | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 125 LPW and less than 140 LPW | **$25.28** | **$31.75** | **$6.47** |
| LT513; LT503 – LT511 odd | LED linear ambient new Luminaires and Retrofit kits rated greater than or equal to 140 LPW | **$25.28** | **$33.13** | **$7.85** |

# References:

1. US Department of Energy, “2015 U.S. Lighting Market Characterization,” prepared by Navigant Consulting. November 2017. Accessed at <https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf>. 66% energy use = (162 + 29)/(237 + 53) Commercial & Indistrial is shown in Table 4.8 p.60; 78% Commercial & 90% Industrial lamp penetration shown in Table 4.2, p.49. [↑](#endnote-ref-1)
2. [A Comprehensive Store Retrofit to LED lighting in Common Lighting Applications,](http://energy-solution.com/wp-content/uploads/2015/01/A-Comprehensive-Store-Retrofit-to-LED-Lighting-in-Common-Lighting-Applications_ETCC-2014.pdf) March 2014; and [LED Office Lighting and Advanced Lighting Control System (ALCS)](https://www.etcc-ca.com/sites/default/files/reports/ET11PGE3251%20LED%20Office%20Lighting%20With%20ALCS.pdf), November 2012. [↑](#endnote-ref-2)
3. Code of Federal Regulations [10 CFR 430.32(n)](http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf) ; accessed at <http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/70> [↑](#endnote-ref-3)
4. Fed Register 2011-28451.pdf ; accessed at <http://www.gpo.gov/fdsys/pkg/FR-2011-11-14/pdf/2011-28451.pdf> [↑](#endnote-ref-4)
5. 2016 Building Energy Efficiency Standards for Residential and Non-Residential Buildings. See Section 140.6 tables B, C, and D (pages 207-210) and Section 140.7 tables A and B (pages 213-5). Accessed at <https://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf> [↑](#endnote-ref-5)
6. 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-6)
7. 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-7)
8. [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-8)
9. Meeting Notes\_04042018\_CS EAR and PGE\_Lighting Workpapers Status Update & Meeting Notes\_04052018\_CS EAR and PGE\_Lighting Workpapers Status Update [↑](#endnote-ref-9)
10. Meeting Notes\_04042018\_CS EAR and PGE\_Lighting Workpapers Status Update & Meeting Notes\_04052018\_CS EAR and PGE\_Lighting Workpapers Status Update [↑](#endnote-ref-10)
11. CALiPER Snapshot Report. DOE. December 7, 2016. <https://energy.gov/sites/prod/files/2016/12/f34/snapshot2016_troffers.pdf> [↑](#endnote-ref-11)
12. 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-12)
13. Measure Labor Cost is product of Installation time and Labor Rate. Labor rate of $70.11 per hour taken from RS Means for PG&E Territory cities. Installation time of 1.509 hours per fixture (0.39 hours per kilolumen) taken from RS Means, Interior LED Fixtures Line # 265113551000; accessed at <http://www.rsmeans.com> [↑](#endnote-ref-13)