**Work Paper PGECOLTG179**

**LED Ambient Commercial Fixtures and Retrofit Kits**

**Revision # 3**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**LED Ambient Commercial Fixtures and Retrofit Kits**

**Measure Codes LT042 – LT063**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LT042 – LT063 |
| **Measure Description:** | LED Luminaires/Retrofit Kits rated ≥110 LPW, Ambient Interior Commercial Spaces |
| **Energy Impact Common Units:** | Kilolumen of LED initial light output |
| **Base Case Description:** | Linear fluorescent recessed fixture or kit in 2x4, 2x2 or 1x4 size, with lamp and ballast meeting federal standard.  Source: PG&E Calculations. |
| **Base Case Energy Consumption:** | Various. Refer to .xlsx file attached  Source: PG&E Calculations. |
| **Measure Energy Consumption:** | Various. Refer to .xlsx file attached  Source: PG&E Calculations. |
| **Energy Savings (Base Case – Measure):** | Various. Refer to .xlsx file attached  Source: PG&E Calculations. |
| **Costs Common Units:** | $ per kilolumen. |
| **Base Case Equipment Cost ($/kilolumen):** | Various. Refer to .xlsx file attached.  Source: Distributor Quotations and Weblinks |
| **Measure Equipment Cost ($/kilolumen):** | Various. Refer to .xlsx file attached  Source: Manufacturer Rep & Distributor Quotations and Weblinks |
| **Gross Measure Cost ($/kilolumen)** | Various. Refer to .xlsx file attached  Source: Manufacturer Rep & Distributor Quotations and Weblinks |
| **Measure Incremental Cost ($/kilolumen):** | Various. Refer to .xlsx file attached  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:** | ROB, NC. |
| **Net-to-Gross Ratios:** | NTG=0.7 All-Default<=2yrs, PreRebDown-2016, PreRebUp-2016, Direct Install-2017  Source: DEER 2016 |
| **Important Comments:** |  |

# 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) |

# Table of Contents

[At-a-Glance Summary ii](#_Toc468797896)

[Document Revision History iii](#_Toc468797897)

[Table of Contents iv](#_Toc468797898)

[List of Tables v](#_Toc468797899)

[Section 1. General Measure & Baseline Data 1](#_Toc468797900)

[1.1 Product Measure Description & Background 1](#_Toc468797901)

[1.2 Product Technical Description 2](#_Toc468797902)

[1.3 Measure Application Type 3](#_Toc468797903)

[1.4 Product Base Case and Measure Case Data 3](#_Toc468797904)

[1.4.1 DEER Base Case and Measure Case Information 4](#_Toc468797905)

[1.4.2 Codes & Standards Requirements Base Case and Measure Information 6](#_Toc468797906)

[1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 6](#_Toc468797907)

[1.4.4 Assumptions and Calculations from other sources – Base and Measure Cases 7](#_Toc468797908)

[Section 2. Calculation Methods 8](#_Toc468797909)

[2.1 Electric Energy Savings Estimation Methodologies 9](#_Toc468797910)

[2.2. Demand Reduction Estimation Methodologies 9](#_Toc468797911)

[2.3. Gas Energy Savings Estimation Methodologies 9](#_Toc468797912)

[Section 3. Load Shapes 10](#_Toc468797913)

[3.1 Base Case Load Shapes 10](#_Toc468797914)

[3.2 Measure Load Shapes 10](#_Toc468797915)

[Section 4. Base Case & Measure Costs 11](#_Toc468797916)

[4.1 Base Case Costs 11](#_Toc468797917)

[4.2 Measure Costs 11](#_Toc468797918)

[4.3 Incremental & Full Measure Costs 12](#_Toc468797919)

[4.3.1 Full Measure Cost 12](#_Toc468797920)

[4.3.2 Incremental Measure Costs 13](#_Toc468797921)

[References: 14](#_Toc468797922)

# List of Tables

[Table 1 - LED Ambient Commercial Fixtures & Retrofit Kits Minimum Measure Efficacies 1](#_Toc468795519)

[Table 2 - Measure Application Type 3](#_Toc468795520)

[Table 3 - LED Ambient Commercial Fixtures & Retrofit Kits Base and Measure Wattages 4](#_Toc468795521)

[Table 4 - Net-to-Gross Ratios 5](#_Toc468795522)

[Table 5 - Installation Rate 5](#_Toc468795523)

[Table 6 - LED Ambient Commercial Fixtures & Retrofit Kits Base and Measure Wattages 8](#_Toc468795524)

[Table 7 - LED Ambient Commercial Fixtures & Retrofit Kits Base Case Cost Table 11](#_Toc468795525)

[Table 8 - LED Ambient Commercial Fixtures & Retrofit Kits Measure Cost Table 11](#_Toc468795526)

[Table 9 - LED Ambient Commercial Fixtures & Retrofit Kits Full Measure Cost 12](#_Toc468795527)

[Table 10 - LED Ambient Commercial Fixtures & Retrofit Kits Incremental Cost 13](#_Toc468795528)

# 

# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Catalog Description***

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

**Requirements:**

* Must be a one for one replacement for a Linear Fluorescent Fixture with T8 or T5 lamps
* Must be a Design Lights Consortium (DLC) approved New Luminaire or an Integrated Retrofit Kit, listed on the PG&E qualified product list as Luminaires/Integrated Retrofit Kits for Ambient Lighting of Interior Commercial Spaces in one of the following sizes: 2x4, 2x2, 1x4
* Must be listed as DLC Premium by the Design Lights Consortium
* DLC-listed initial light output must be ≥ 2200 lm and ≤ 6500 lm
* Linear LED replacement lamps do not qualify
* LED Linear Retrofit kits on the PG&E QPL do not qualify.
* Only Fixtures and Retrofit kits that include new lenses between the LED package and the viewer qualify.
* Self-ballasted or screw-based lamps do not qualify.
* 5-year warranty minimum
* Must meet the minimum efficacy requirements listed in Table 1.

Table - LED Ambient Commercial Fixtures & Retrofit Kits Minimum Measure Efficacies

|  |  |
| --- | --- |
| LT042 | 2x4 LED new Luminaire rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT043 | 2x4 LED new Luminaire rated ≥125 LPW, Ambient Interior Commercial Spaces |
| LT046 | 2x2 LED new Luminaire rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT047 | 2x2 LED new Luminaire rated ≥125 LPW, Ambient Interior Commercial Spaces |
| LT050 | 1x4 LED new Luminaire rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT051 | 1x4 LED new Luminaire rated ≥125 LPW, Ambient Interior Commercial Spaces |
| LT054 | 2x4 LED Integrated retrofit kit rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT055 | 2x4 LED Integrated retrofit kit rated ≥125 LPW, Ambient Interior Commercial Spaces |
| LT058 | 2x2 LED Integrated retrofit kit rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT059 | 2x2 LED Integrated retrofit kit rated ≥125 LPW, Ambient Interior Commercial Spaces |
| LT062 | 1x4 LED Integrated retrofit kit rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces |
| LT063 | 1x4 LED Integrated retrofit kit rated ≥125 LPW, Ambient Interior Commercial Spaces |

***Program Restrictions and Guidelines***

This workpaper details the replacement of linear fluorescent fixtures with LED Ambient Commercial Fixtures & Integrated Retrofit Kits. The workpaper offers delivery methods for non-residential customers through Upstream/Midstream, Downstream, or Direct Install Deemed programs.

The LED fixture or integrated retrofit kit must replace a linear fluorescent fixture on a 1-for-1 basis.

DLC requirements for Integrated Retrofit Kits and Luminaires for Ambient Lighting of Interior Commercial Spaces include:

* 5-year warranty
* 50,000 hour L70 Lumen Maintenance
* 36,000 hour L90 Lumen Maintenance
* ≥ 80 Color Rendering Index (CRI)
* ≥ 110 lumens / Watt
* ≤ 5000 Kelvin Correlated Color Temperature (CCT)
* 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 Categories Eligible under this Workpaper:** |
| * Must be on PG&E Qualified Products List, in one of 6 DLC categories:   + 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   + 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces   + Integrated Retrofit Kits for 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces |

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.

**Type of Transaction:**

The applicable types of transactions include Replace on Burnout or New Construction. The rebate incentivizes the choice of energy efficient equipment over the base case equipment, which is a Linear Fluorescent T8 fixture or retrofit kit.

## 1.2 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: T8 lamps predominate currently, 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 4 foot lamps also common.

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 72% of energy use in the commercial lighting sector and 80% of all commercial light fixtures, and therefore represents an enormous opportunity for potential LED savings.[[1]](#endnote-1)

LED Ambient Commercial products, which are most commonly used in recessed ceilings but may also be surface-mounted or suspended, 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 Technology 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 ET11PGE3251.4,5

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 LED panel fixtures feasible. These are fixtures with output of at least 1,500 lumens. Currently DLC requires LED panels and kits achieve output of at least 1,500 lumens. Panels eligible for these measure codes shall have initial light output rated between 2,200 lumens and 6,500 lumens.

LED fixtures under this workpaper are assigned a measure code according to efficacy, fixture type, and fixture size. The energy impact common unit is the kilolumen of initial rated light output for the LED fixture, according to the DLC listing.

This workpaper describes the energy savings associated with the replacement of linear fluorescent fixtures.

## 1.3 Measure Application Type

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

Table  - Measure Application Type[[2]](#endnote-2)

Identifies the measure application type in the Measure Implementation table in DEER2011.

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

## 1.4 Product Base Case and Measure Case Data

Eligible measure case fixtures for these measure codes are LED panels with initial light output between 2,200 and 6,500 lumens. Appropriate base case fixtures are linear fluorescent fixtures that will have equivalent maintained illuminance to those LEDs at the end of effective useful life. The Effective Useful Life is 50,000 hours based on the DLC-minimum rated hours, except where this value exceeds the DEER run hours for a given building type over the 16 year DEER measure maximum life, in which case the effective useful life is 16 years. Given the great number of variations on linear fluorescent lamp and ballast configurations and resultant light outputs, and that groupings made by wattage as in previous custom do not accurately reflect illumination between LED and linear fluorescent fixtures, the efficacy and wattages of both base case and measure case fixtures are not grouped by lamp and ballast configuration but characterized in units of kilolumens of initial LED light output with energy impacts scaling with these kilolumen units. Cost, wattage and savings are all in units of kilolumen.

Table - LED Ambient Commercial Fixtures & Retrofit Kits Base and Measure Wattages

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Description** | **Base Case system wattage**  **per kilolumen (COM)** | **LED Watts per kilolumen** | **Delta Watts per kilolumen**  **(COM)** |
| LT042, LT046, LT050, LT054, LT058, LT062 | LED Luminaires/Retrofit Kits rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | 14.8 | 9.1 | 5.7 |
| LT043, LT047, LT051, LT055, LT059, LT063 | LED Luminaires/Retrofit Kits rated ≥125 LPW, Ambient Interior Commercial Spaces | 14.8 | 8.0 | 6.8 |

### 1.4.1 DEER Base Case and Measure Case Information

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

**Net-to-Gross Assumption:**

The NTGR value is from DEER 2016[[3]](#endnote-3). Table 4 summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

The LED commercial lighting fixtures (troffer) product category is rapidly evolving as product quality continues to improve and price continues to come down. However, high initial cost and product quality variability are still enough of market barriers that a utility incentive program could help to address these barriers by providing incentives to reduce initial cost, coupled with product qualification standards. This will allow utilities to accelerate market adoption of high quality products. The long lifetime of LED products means that retrofits will occur far less frequently than before, increasing the importance of selecting high quality products and ensuring customer satisfaction.

***Emerging Technology Study for this Measure***

The LED commercial lighting fixtures (troffer) product category is rapidly evolving as product quality continues to improve and price continues to come down. However, high initial cost and product quality variability are significant concerns in this product segment. PG&E commissioned two Emerging Technology (ET) studies to examine these products thoroughly before launching a deemed measure.

The goals of these studies included: evaluating product quality, developing information to address product cost concerns, determining the appropriate timing for launching a commercial deemed measure, and understanding customer satisfaction issues.

PG&E’s ET Program initiated ET projects in 2011 and 2012 to study these measures.

Project ET12PGE1481 conducted a comprehensive LED retrofit in a retail store environment with multiple fixture and lamp types. It confirmed that completing a store-wide, comprehensive LED retrofit is feasible. Overall, the project achieved a 58% reduction in energy use for LEDA eligible products, and 47% on a store-wide basis. The study participant was very satisfied with the energy savings, projected maintenance savings, and lighting quality provided by the LED products that were installed.[[4]](#endnote-4)

Project ET11PGE3251 demonstrated LED panel fixtures in an office lighting application with an Advanced Lighting Control System (ALCS). It demonstrated that it is easier to integrate controls with the latest LED products in the market which increases the potential for even deeper savings. An initial energy savings of 21% resulted from replacing fluorescent lighting with LED lighting in an office. A further energy savings of 41% resulted from adding the ALCS.[[5]](#endnote-5)

These two ET projects together outlined the path forward for these projects in non-residential deemed programs. The results suggested that a utility incentive program could help to address market barriers by providing incentives to reduce initial cost, coupled with rigorous product qualification standards. This will allow utilities to accelerate market adoption of high-quality products. The long lifetime of LED products means that retrofits will occur far less frequently than before, increasing the importance of selecting high-quality products and ensuring customer satisfaction.

Based on the August 23, 2015 disposition, 0.85 ET\_NTG was used in direct install delivery channel. The upstream and downstream channels will use the 0.7 NTG as noted in the disposition. The ET\_NTG for Direct Install was effective to the portfolio since 10/1/2015 and expires on 12/31/2016. The NTG for All-Default<=2yrs will be used until 10/1/2017 and will be changed to 0.6 thereafter.

Table - Net-to-Gross Ratios

|  |  |  |  |
| --- | --- | --- | --- |
| **Delivery Type** | **NTGR\_ID** | **Description** | **NTG** |
| PreRebDown-2016 | All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | 0.7 |
| DirInstall | All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | 0.7 |
| PreRebUp-2016 | All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | 0.7 |

**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 - Installation Rate

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

**Effective Useful Life / Remaining Useful Life**

The rated life for these products is assumed to be 50,000 hours, the minimum DLC specification. Rated life for DLC-listed products varies between 50,000 hours and 500,000 hours. Since the EUL is dependent on the DEER hours of operation, the EUL expressed in years varies by building type. DEER sets an EUL maximum of 16 years for Interior Linear Fluorescent Fixtures, which this workpaper proposes applying to these LED fixtures and retrofit kits (16 year EUL maximum, equivalent of equivalent of ILtg-Com-LED-50000hr+16yr and ILtg-Res-LED-50000hr+16yr, DEER2016).

The EUL is based on 50,000 hours rated fixture life divided by average annual hours of operation for each building type, with a maximum of 16 years:

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

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

***Title 20:*** These measures do not fall under Title 20 [2015] of the California Energy Regulations.

***Title 24:*** These measures do not fall under Title 24 [2013] of the California Energy Regulations. The Lighting Power Densities of both measure and base case are capped by Title 24, but both measure and base cases are configured so as to be compliant with Title 24, with the measure capturing savings above Title 24 minimums.

***Federal Standards:*** These 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)[[6]](#endnote-6)
2. Ballasts for 4-foot medium bi-pin lamps are required by EPCA’s 2011 amendment to have a luminous efficacy no less than 0.993/(1 + 0.27 ͯ total lamp arc power - 0.25)[[7]](#endnote-7)

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

#### 1.4.3.1 CALiPER Application Summary Report 13:[[8]](#endnote-8)

A few of the conclusions that CALiPER reported in its most recent application summary report on LED Panels (#13 from 2011) from tests of 6 LED 2x2 troffer fixtures:

* LED products tested were more efficacious and produced more light output that some, but not all, of the fluorescent benchmark products
* 5 of 6 products performed as claimed in product literature, and one significantly underperformed

5 LED troffers had been tested in a few previous CALiPER reports in 2009 or earlier, with 4 of the 5 having efficacies similar to fluorescent benchmarks, and with typically lower spacing criteria.

#### 1.4.3.2 PG&E Emerging Technology Studies:

PG&E commissioned two Emerging Technology studies in recent years to identify and develop information on interior commercial applications.

Project ET12PGE1481 conducted a comprehensive LED retrofit in a retail store environment with multiple fixture and lamp types. It confirmed that completing a store-wide, comprehensive LED retrofit is not only feasible, but cost-effective as well. Overall, the project achieved a 58% reduction in energy use for LEDA eligible products, and 47% on a store-wide basis. The study participant was very satisfied with the energy savings, projected maintenance savings, and lighting quality provided by the LED products that were installed.4

This project evaluated six different lighting applications in eight store study areas, evaluating energy consumption and lighting performance in each area. Interior applications included A-lamp shape, Directional, MR16, Decorative, Downlight, Troffer, and High-bay. The projects found cost-effective retrofit options store-wide, including a return-on-investment of 17.3% for measures eligible for the LEDA advanced incentive program.

Project ET11PGE3251 demonstrated LED panel fixtures in an office lighting application with an Advanced Lighting Control System (ALCS). It demonstrated that it is easier to integrate controls with the latest LED products in the market which can help achieve even deeper savings. An initial energy savings of 21% resulted from replacing fluorescent lighting with LED lighting in an office. A further energy savings of 41% resulted from adding the ALCS.5

This study focused on a Class A commercial office space, and used a phased approach to study different levels of control (task-tuning, occupancy-sensing, daylight-sensing, individual dimming) in conjunction with LED fixtures. The LED luminaires were found to be highly configurable for these multiple control strategies, making them attractive to customers at the leading edge of technology adoption in both the workplace data and lighting product segments. Customers who have interest in maximizing both individualized distributed environmental control and sustainable energy saving practices will be particularly attracted to these options. The payback on the combined luminaire and controls retrofit was very high (generally > 50 years), but customers looking for workplace data benefits or already planning fixture replacement will see a lower incremental cost. The study recommended LED sources for this application based on several benefits: “lighting distribution, color rendering, and color temperature which are comparable to or better than fluorescent sources.”

Linear fluorescent lighting represents 72% of energy use in the commercial lighting sector and 80% of all commercial light fixtures, and therefore represents an enormous opportunity for potential LED savings. Due to the high efficacy of linear fluorescent lamps, there have only recently been suitable LED replacements for traditionally linear fluorescent applications, such as general purpose commercial lighting.

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

The fixture performance in the applicable categories of the DLC list—LED Luminaires and Retrofit Kits for Ambient Lighting of Interior Commercial Spaces—was analyzed to justify the light output equivalency assumptions. The 6,840 fixtures in these categories were analyzed for luminaire efficacy.

**Delta Wattage Assumption (ΔW)**

The base case linear fluorescent fixtures were modeled across the DLC light output range according to the most common fixture type in a configuration meeting appropriate Federal lamp standards, Federal ballast standards, and California Title 24 (T24) interior commercial lumen power density (LPD) requirements. Rather than assume a single base case lamp-and-ballast-and-fixture combination as a base case, the efficacy of a standards-compliant base case fixture in terms of lumens per Watt (LPW) is used to calculate savings.

The code-compliant base case fixture model used is from the 2011 Codes and Standards Enhancement (CASE) Report for Indoor Lighting Controls.[[9]](#endnote-9) This report developed the most thorough commercial interior lighting model available in California standards proceedings. The model used by CASE author offers a combination of interior spaces: large open-plan areas as found in many offices, as well as small spaces typical of private offices or meeting rooms. The panel fixtures modeled are 2x4 3-lamp T8 parabolic fixtures, matching a typical parabolic luminaire with 74.7% fixture efficacy.[[10]](#endnote-10)

The model was updated to 2013-T24 LPD specifications, which reduce LPDs for Office Buildings via the Complete Building Method from 0.9 W/sf to 0.8 W/sf.[[11]](#endnote-11) The 0.8 W/s.f. value used is lower than other applicable building types in Table 140.6-B of 2013-T24: 1.0 W/s.f. for General Commercial/Industrial Work Buildings, 1.2 W/s.f. for Restaurant Buildings, and 1.0 W/s.f. for School Buildings. The model was changed to reflect Federal fluorescent lamp minimum standards with a 2950-lumen lamp, but the ballast was unchanged as it reflected a premium electronic ballast listed by the Consortium for Energy Efficiency’s HPT8 standard and the National Electrical Manufacturers Association’s NEMA Premium listing. The CASE Report model’s assumption for Light Loss of 9.7% was used. The model suggests that illumination from recessed fluorescent fixtures compliant with current code can be obtained at maintained fixture efficacy of 58.8 LPW. This figure is higher, accounting for 9.7% lumen depreciation, than the 5 fluorescent benchmark troffer fixtures tested in CALiPER Rounds 9 and 13 (all of which were 2x2 fixtures).[[12]](#endnote-12)

The 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 2015 given LED improvements. Given their age, CALiPER reports were not used for determining equivalency.

Initial LED lumen efficacy assumptions are set by the measure code minimum requirements, starting with 110 LPW for the lowest-efficacy measure code corresponding with DLC’s Premium tier minimum efficacy. Calculating the wattage corresponding to this efficacy for a unit of one kilolumen can be accomplished by dividing 1000 lumens by 110 lumens per watt, resulting in 9.1 Watts per kilolumen for the measure case. The LED fixture performance calculation relies on the fact that test lamp performance for LED fixtures is measured via absolute photometry, compared to the relative photometry which is the standard for linear fluorescent fixtures. The practical implication of this is that the LED product efficacies found in the DLC Premium listing, 110 LPW and higher, already reflect the light losses inside the fixture, giving an 110-LPW LED fixture a significant advantage in supplying illumination over a fluorescent fixture with an 110 LPW lamp-and-ballast system.

Maintained lumen output equivalency was based on the full list of DLC products and on LED lumen maintenance data from the Lighting Facts database. All 156 Lighting Facts fixtures with lumen maintenance information were considered as a full dataset, as well as the subset of 20 fixtures that were both DLC-listed and available with lumen maintenance values for the 25,000-hour mark, the mid-point of the 50,000 DLC specification minimum. The full dataset is provided in the calculations file for this workpaper. Analysis of both the full set and subset, in accordance with the LED lumen output extrapolation formula published in Federal rulemaking,[[13]](#endnote-13) suggests LED fixture lumen maintenance at EUL of 89.6% for the blended Commercial building type with 2420 DEER Measure hours per year for 16 years, based on the following calculation:

Com EUL hours per DEER = DEER Annual Measure HOUstd ͯ EUL fixture maximum

= 2420 hours/year ͯ 16 year maximum EUL

= 38720 hours

This is less than 50,000, so 38720 hour EUL is used for Com building type

LED lumen maintenance varies by building type due to differing DEER run hours. Motel annual run hours of 1000 result in 16,000 run hours over 16 year EUL and thus 95.5% lumen maintenance. DEER annual run hours in half of the DEER building types, including the Large Retail, Restaurant and Grocery, over 16 years will exceed 50,000 hours, so the 50,000 DLC-minimum rated life fixture is used, along with an 89.6% lumen maintenance figure. The calculation, based on the Federal extrapolation formula, is taken across all 20 DLC-listed fixtures with 25,000-hour Lighting Facts data available, as follows:

Lumen Maintenance at Com EUL =

=

=89.6% lumen maintenance

# 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 the methods described in section 1.4.4.

Table - LED Ambient Commercial Fixtures & Retrofit Kits Base and Measure Wattages

|  |  |  |  |
| --- | --- | --- | --- |
| **Base Case** | **Base Case Wattage** | **Measure Case Wattage** | **Delta Wattage** |
| LED Luminaires/Retrofit Kits rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | 14.8 – 15.9 | 9.1 | 5.7 – 6.8 |
| LED Luminaires/Retrofit Kits rated ≥125 LPW, Ambient Interior Commercial Spaces | 14.8 – 15.9 | 8.0 | 6.8 – 7.9 |
| Base case wattage varies by building type | | | |

## 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 = 14.8 W – 9.1 W = 5.7

**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) / 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.

Table - LED Ambient Commercial Fixtures & Retrofit Kits Base Case Cost Table

|  |  |
| --- | --- |
| **Measure Description** | **Base Case Equipment Cost** |
| All LED Luminaires/Retrofit Kits Measures for Ambient Interior Commercial Spaces | $ 15.55 |

## 4.2 Measure Costs

The measure equipment costs were developed from California distributor catalogs and websites and confirmed with manufacturer representatives where possible. There are no DLC products qualified for LT063, 1x4 retrofit kits > 125 LPW, so costs for this measure code are based on the new fixture costs in this shape and efficacy because retrofit kit and new luminaire prices are the same for the 2x2 and 2x4 sizes.

Table - LED Ambient Commercial Fixtures & Retrofit Kits Measure Cost Table

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Description** | **Measure Equipment Cost** |
| LT042 | 2'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$34.72** |
| LT043 | 2'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$31.41** |
| LT046 | 2'x2' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$33.10** |
| LT047 | 2'x2' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$37.48** |
| LT050 | 1'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$34.71** |
| LT051 | 1'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$38.94** |
| LT054 | 2'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$35.05** |
| LT055 | 2'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$31.28** |
| LT058 | 2'x2' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$38.67** |
| LT059 | 2'x2' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$37.48** |
| LT062 | 1'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$40.83** |
| LT063 | 1'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$38.94** |

## 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** |
| ER | Measure Equipment Cost  +Measure Labor Cost | (-1)x(Base Equipment Cost  + Base Labor Cost) | Measure Equipment Cost  – Base Case Equipment Cost |
| 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, till then the following costs will be used for direct install.

FMC = Measure Equipment Cost + Measure Labor Cost

Table - LED Ambient Commercial Fixtures & Retrofit Kits Full Measure Cost

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Measure Code | Measure Description | **Measure Equipment Cost** | **Measure Labor Cost[[14]](#endnote-14)** | **Full**  **Measure Cost** |
| LT042 | 2'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$34.72** | $27.06 | **$61.78** |
| LT043 | 2'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$31.41** | $27.06 | **$58.47** |
| LT046 | 2'x2' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$33.10** | $27.06 | **$60.16** |
| LT047 | 2'x2' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$37.48** | $27.06 | **$64.54** |
| LT050 | 1'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$34.71** | $27.06 | **$61.77** |
| LT051 | 1'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$38.94** | $27.06 | **$66.00** |
| LT054 | 2'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$35.05** | $27.06 | **$62.10** |
| LT055 | 2'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$31.28** | $27.06 | **$58.34** |
| LT058 | 2'x2' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$38.67** | $27.06 | **$65.73** |
| LT059 | 2'x2' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$37.48** | $27.06 | **$64.54** |
| LT062 | 1'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$40.83** | $27.06 | **$67.89** |
| LT063 | 1'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$38.94** | $27.06 | **$66.00** |

### 4.3.2 Incremental Measure Costs

The labor costs for measure and base cases are equivalent.

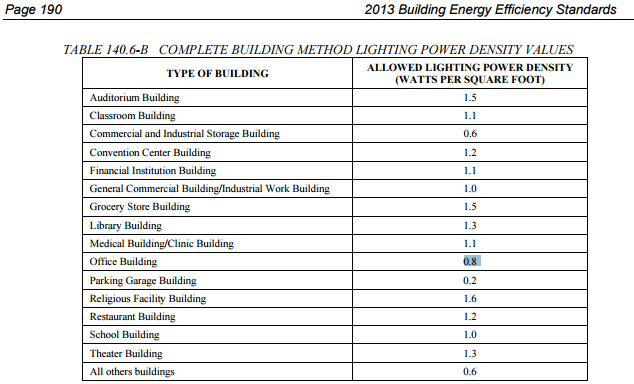
Incremental cost (INCR) = Measure Cost – Base Case Cost

Table - LED Ambient Commercial Fixtures & Retrofit Kits Incremental Cost

|  |  |  |
| --- | --- | --- |
| Measure Code | **Measure Description** | **Incremental Measure Cost** |
| LT042 | 2'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$19.17** |
| LT043 | 2'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$15.86** |
| LT046 | 2'x2' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$17.55** |
| LT047 | 2'x2' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$21.93** |
| LT050 | 1'x4' LED new Luminaire; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$19.16** |
| LT051 | 1'x4' LED new Luminaire; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$23.39** |
| LT054 | 2'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$19.49** |
| LT055 | 2'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$15.73** |
| LT058 | 2'x2' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$23.12** |
| LT059 | 2'x2' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$21.93** |
| LT062 | 1'x4' LED Integrated retrofit kit; rated ≥110 and <125 LPW, Ambient Interior Commercial Spaces | **$25.28** |
| LT063 | 1'x4' LED Integrated retrofit kit; rated ≥125 LPW, Ambient Interior Commercial Spaces | **$23.39** |

# References:

1. US Department of Energy, “2010 U.S. Lighting Market Characterization,” prepared by Navigant Consulting. January 2012. Accessed at [http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf](https://urldefense.proofpoint.com/v2/url?u=http-3A__apps1.eere.energy.gov_buildings_publications_pdfs_ssl_2010-2Dlmc-2Dfinal-2Djan-2D2012.pdf&d=BQMFAg&c=hLS_V_MyRCwXDjNCFvC1XhVzdhW2dOtrP9xQj43rEYI&r=TlrXy5TrK8nTfd5c4pv-ow&m=A_sWUgFERFjw3F_leslWM3ZqPLimv_rw4h-6rQsY4js&s=SsFH0JL36jCn7uudgFNPVrNA4dqEg5cU5zA__Kn99mU&e=). 72% energy use is shown in Table 4.8; 80% lamp penetration shown in Table 4.2. [↑](#endnote-ref-1)
2. The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata\_format-V0.97.xls.* [↑](#endnote-ref-2)
3. DEER2016, see calculations workbook [↑](#endnote-ref-3)
4. A Comprehensive Store Retrofit to LED lighting in Common Lighting Applications. PG&E Emerging Technologies Program. Accessed at <http://www.etcc-ca.com/sites/default/files/reports/ET12PGE1481%20Retail%20LED%20updated%2003132014.pdf>. [↑](#endnote-ref-4)
5. LED Office Lighting and Advanced Lighting Control System (ALCS). PG&E Emerging Technologies Program. Accessed at: <http://www.etcc-ca.com/sites/default/files/reports/ET11PGE3251%20LED%20Office%20Lighting%20With%20ALCS.pdf>. [↑](#endnote-ref-5)
6. 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-6)
7. Fed Register 2011-28451.pdf ; accessed at <http://www.gpo.gov/fdsys/pkg/FR-2011-11-14/pdf/2011-28451.pdf> [↑](#endnote-ref-7)
8. CALiPER Summary Report Round 13. DOE. October 2011. [↑](#endnote-ref-8)
9. CASE\_Nonres\_Indoor\_Lighting\_Controls.pdf; accessed at <http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_Indoor_Lighting_Controls.pdf> [↑](#endnote-ref-9)
10. Cooper\_2P2GAX332\_3L\_T8\_18C\_spec-sheet.pdf; accessed at <http://www.cooperindustries.com/content/dam/public/lighting/products/documents/metalux/spec_sheets/090386_2P2GAX332_3L_T8_18C.pdf> [↑](#endnote-ref-10)
11. CEC-Title24-2013.pdf, p. 205 (header indicating p. 190); accessed at <http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf>

    Table 140.6-B reads as follows:  [↑](#endnote-ref-11)
12. CALiPER Summary Report Round 13, chart p. 21. DOE. October 2011. [↑](#endnote-ref-12)
13. Fed Register 2014-12127.pdf p. 17; accessed at <http://www.gpo.gov/fdsys/pkg/FR-2014-06-03/pdf/2014-12127.pdf> [↑](#endnote-ref-13)
14. 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-14)