

Work Paper PGECOLTG139
LED Surface, Pendant, Track, Accent,
and Recessed Downlight
Revision 10

Pacific Gas & Electric Company
Customer Energy Solutions

LED Surface, Pendant,
Track, Accent, and
Recessed Downlight

Measure Codes: LD127-LD146

08/10/2017

At-A-Glance Summary

| Applicable Measure Codes: | LD127-LD146 | | | | | | | | | | | | | | | | | |
|--------------------------------------|---|---|--|---------|------|--------|----------------------|-----|---|-------------------|-----|------------------------------|------------------|-----|-----------|---------------|------|-----------|
| Measure Description: | LED surface, pendant, track, accent, and recessed downlight fully integrated retrofit kit replacing incandescent BR30, R30, BR40, MR16, R40 or halogen PAR30 or PAR38 fixture. | | | | | | | | | | | | | | | | | |
| Energy Impact Common Units: | Fixture. | | | | | | | | | | | | | | | | | |
| Base Case Description: | Various: Refer to .xlsx file attached Source: Energy Division ,WRR Lighting LED Disposition – July, 2016 | | | | | | | | | | | | | | | | | |
| Base Case Energy Consumption: | Various: ED LED Fixture wattage reduction ratio, Refer to .xlsx file attached Source: Energy Division ,WRR Lighting LED Disposition – July, 2016 | | | | | | | | | | | | | | | | | |
| 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 fixture. | | | | | | | | | | | | | | | | | |
| Base Case Equipment Cost (\$/unit): | Various: Refer to .xlsx file attached Source: PG&E Calculations. | | | | | | | | | | | | | | | | | |
| Measure Equipment Cost (\$/unit): | Various: Refer to .xlsx file attached Source: PG&E Calculations. | | | | | | | | | | | | | | | | | |
| Measure Incremental Cost (\$/unit): | Various: Refer to .xlsx file attached Source: PG&E Calculations. | | | | | | | | | | | | | | | | | |
| Effective Useful Life (years): | ILtg-Res-LED-50000hr, 16 years ILtg-Com-LED-50000hr, Varies Source: DEER 2016 | | | | | | | | | | | | | | | | | |
| Program Type: | ROB or NC | | | | | | | | | | | | | | | | | |
| Net-to-Gross Ratios: | <table><tr><th>NTGR ID</th><th>NTGR</th><th>Source</th></tr><tr><td>NonRes-sAll-mLEDSpcl</td><td>0.6</td><td>Preliminary Ex Ante database¹</td></tr><tr><td>Res-sAll-mLEDSpcl</td><td>0.6</td><td>Preliminary Ex Ante database</td></tr><tr><td>Com-Default>2yrs</td><td>0.6</td><td>DEER 2016</td></tr><tr><td>Res-Default>2</td><td>0.55</td><td>DEER 2016</td></tr></table> | | | NTGR ID | NTGR | Source | NonRes-sAll-mLEDSpcl | 0.6 | Preliminary Ex Ante database ¹ | Res-sAll-mLEDSpcl | 0.6 | Preliminary Ex Ante database | Com-Default>2yrs | 0.6 | DEER 2016 | Res-Default>2 | 0.55 | DEER 2016 |
| NTGR ID | NTGR | Source | | | | | | | | | | | | | | | | |
| NonRes-sAll-mLEDSpcl | 0.6 | Preliminary Ex Ante database ¹ | | | | | | | | | | | | | | | | |
| Res-sAll-mLEDSpcl | 0.6 | Preliminary Ex Ante database | | | | | | | | | | | | | | | | |
| Com-Default>2yrs | 0.6 | DEER 2016 | | | | | | | | | | | | | | | | |
| Res-Default>2 | 0.55 | DEER 2016 | | | | | | | | | | | | | | | | |
| Important Comments: | Replaced NTG IDs “NonRes-sAll-MLtgLED-Deemed” and “Res-sAll-MLtgLED-Deemed which expired 6/30/2017 with NonRes-sAll-mLEDSpcl and Res-sAll-mLEDSpcl respectively. | | | | | | | | | | | | | | | | | |

Document Revision History

| Revision # | Date | Description | Author (Company) |
|-------------|------------|---|--|
| Revision 0 | 09/24/08 | Original work paper. | Marc Theobald (EES), Jack Howells (EES) |
| Revision 1 | 12/10/09 | | Jim Wyatt (PG&E) |
| Revision 2 | 1/14/2010 | | Jim Wyatt (PG&E) |
| Revision 3 | 6/27/2012 | Expanded to 3 measures. Updated for 2013–2014 program years based on DEER 2011 v4.01 | John Rossi (EES), Jay Martin (EES); Reviewed by Alina Zohrabian (PG&E) |
| Revision 3 | 8/28/12 | OTR explanation is added in the workpaper. The “Com” and “RES” building types are the weighted up value from DEER building types, For Vintage AV is changed to EX and For Climate Zone All is changed to IOU | Alina Zohrabian (PG&E) |
| Revision 4 | 7/16/13 | Revised Savings values per ED Workpaper Disposition for Lighting Retrofit, issue March, 2013. For updated savings values, see file PGECOLTG139 R4-Calcs.xlsx For measure LC29 PG&E used 8 watts for the measure wattage this went down to 5 watts. For base case PG&E used a 40 watt incandescent. The base case got adjusted down based on a 2.96 WRR. For measure LC25 PG&E used 10 watts for the measure wattage this didn’t change since this is the lowest wattage in the range. For base case PG&E used a 60 watt incandescent. The base case got adjusted down based on a 2.96 WRR. For measure LC23 PG&E used 15 watts for the measure wattage this went down to 12.1 watts. For base case PG&E used a 95 watt incandescent. The base case got adjusted down based on a 2.96 WRR. | Alina Zohrabian (PG&E) |
| Revision 5 | 10/31/2013 | Measure wattages are broken down into more refined wattage ranges. Please refer to PGECOLTG139 R5-Calcs.xlsx for savings values. These values are to be used for 2014 | Alina Zohrabian (PG&E) |
| Revision 6 | 4/15/2014 | Added DI Component | Breesa Collyer (PG&E) |
| Revision 7 | 5/22/2014 | Revised savings values per ED Workpaper Disposition for Lighting Retrofits, December 14, 2013. For updated savings values, see file PGECOLTG139 R7.xlsx | Mark Tiemens (PG&E) |
| Revision 8 | 1/1/2016 | Expanded application type for New Construction. Updated the base case costs, measure costs, NTG, EUL, hours of operation, CDF, and IE per DEER 2016 | Linda Wan (PG&E)/Alina Zohrabian (PG&E) |
| Revision 9 | 11/28/2016 | -Updated the wattage reduction ratio (WRR), base case wattage, and base case costs as per July 22, 2016 disposition -Updated Annual Hours of Use, CDF, and IE as per DEER 2017 | Mini Damodaran (PG&E)/Alina Zohrabian (PG&E) |
| Revision 10 | 8/10/2017 | Replaced NTG IDs NonRes-sAll-MLtgLED-Deemed and Res-sAll-MLtgLED-Deemed which expired 6/30/2017 with NonRes-sAll-mLEDSpcl and Res-sAll-mLEDSpcl respectively. | Mini Damodaran (PG&E) |

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Section 1. General Measure & Baseline Data

1.1 Measure Description & Background

Catalog Description –

LED SURFACE, PENDANT, TRACK, ACCENT, AND RECESSED DOWNLIGHT:

Table 1 Product Code and Description

| Product Code | Description |
|--------------|--|
| LD127 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install < 7W LED |
| LD128 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 7 to < 8W LED |
| LD129 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 8 to < 9W LED |
| LD130 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 9 to < 10W LED |
| LD131 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 10 to < 11W LED |
| LD132 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 11 to < 12W LED |
| LD133 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 12 to < 13W LED |
| LD134 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 13 to < 14W LED |
| LD135 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 14 to < 15W LED |
| LD136 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 15 to < 16W LED |
| LD137 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 16 to < 17W LED |
| LD138 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 17 to < 18W LED |
| LD139 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 18 to < 19W LED |
| LD140 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 19 to < 20W LED |
| LD141 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 20 to < 21W LED |
| LD142 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 21 to < 22W LED |
| LD143 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 22 to < 23W LED |
| LD144 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 23 to < 24W LED |
| LD145 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install 24 to < 25W LED |
| LD146 | LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install ≥ 25W LED |

Program Requirements and Guidelines

This work paper details the replacement of existing halogen or incandescent fixtures with LED fixtures. The delivery method is Downstream Deemed Programs for commercial customers and the Upstream Lighting Program for residential customers. Multifamily customers can also apply through the downstream multifamily program.

- Rebates are based on a one-for-one replacement of incandescent, halogen, or CFL fixtures up to 100 watts.
- All new LED fixtures must be on the ENERGY STAR commercial qualified product list or Design Lights Consortium (DLC) qualified product list and be listed with the Department of Energy Lighting Facts Program.
- Customers are responsible for verifying that new fixtures work with existing lighting controls.
- Recessed LED downlight fully integrated retrofit kit replacing CFLs, incandescent BR30, R30, BR40, MR16, R40 or halogen PAR30 or PAR38 fixtures. Qualifying product must be on the ENERGY STAR commercial qualified product list or Design Lights Consortium qualified product list and be listed with the Department of Energy Lighting Facts Program.

Program Restrictions and Guidelines

To qualify for a rebate, the following requirements must be met:

- All new LED fixtures must be on the ENERGY STAR commercial qualified product list or DesignLights Consortium qualified product list and be listed with the Department of Energy Lighting Facts Program.
- The LEDs must replace reflector-type CFL, incandescent, PAR halogen, or PAR halogen IR fixtures as a fully integrated LED luminaire (or complete retrofit kit).
- LED screw-in lamps are not eligible under these measures.
- The LEDs must meet a minimum luminaire efficacy of 35 lm/W.
- Downlights intended for installation in insulated ceilings shall be IC rated and be leak tested per ASTM E-283 standard test method² to demonstrate no more than 2.0 cfm at 75 Pa pressure difference, and must display a label certifying “airtight” or similar designation which shows accordance with this requirement.
- A product cut sheet must be provided.

Terms and Conditions

The customer must be a residential or commercial PG&E electrical customer. Single and multi-family installations are eligible.

Market Applicability

Fixtures with halogen PAR lamps are primarily used in the retail market sector; however, this measure applies to all commercial market sectors.

Please refer to the table below for the applicable delivery types, building types, and application types.

Table 2 Delivery Method and Applicable Building Types

| Delivery Type | Applicable Building Types | Application Type |
|-----------------------------|----------------------------------|-------------------------|
| Upstream | “Res” & “Com” | New Construction & ROB |
| Downstream & Direct Install | DEER Building Types | New Construction & ROB |

1.2 Product Technical Description

Light emitting diode (LED) sources have improved over the past decade, making them an efficient lighting technology. Electricity usage for lighting in the U.S. is projected to be 19% lower in 2020 and 46% lower in 2030 if LED lighting is adopted for general illumination applications.³ Many LED products are marketed as incandescent or halogen replacements. The lumen output and efficacy of many LED products are comparable to or exceed that of compact fluorescent, halogen, and incandescent sources.⁴

LED products offer many advantages over conventional lighting products, including energy savings, long operating life, reduced radiated heat, minimal light loss, dim ability and controllability, durability, enhanced performance at low temperatures, safety improvements, smaller package size, uniform illumination, mercury reduction, enhanced product appearance, improved color rendition, and lower lumen depreciation.⁵

These measures are based on replacing incandescent surface, pendant, track, accent and recessed downlight fixtures to use light emitting diode (LED) source illumination. This work paper bases assumptions on Rounds 12 and 14 of the Commercially Available LED Product Evaluation and Reporting (CALiPER) Program of the U.S. Department of Energy.⁶ The products were selected as integrated LED luminaires: existing lamps, ballasts, associated housing and hardware are typically replaced by integral lamp, driver, reflector, trim, and housing or entire fixture head. Conversions without any hard-wired component are considered as screw-in lamp replacements and do not fall within the bounds of this measure.

1.3 Measure Application Type

The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*, defines the terms as follows:

Table 3 Measure Application Type⁷

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 ROB and NC.

1.4 Product Base Case and Measure Case Data

The base case wattage is calculated based on the wattage reduction ratio (WRR) of 2.42 recommended by Energy Division in July 2016, WRR Lighting LED Disposition. The measure case is the associated LED wattage.

1.4.1 DEER Base Case and Measure Case Information

For updated DEER values IDs, see file PGECOLTG139 R9.xlsx

Delta Wattage Assumption (ΔW)

Energy savings are based on wattage reduction ratios per July 22, 2016 disposition.

Hours of Operation

The DEER hours of operation and interactive effects are used for savings calculations.

Net-to-Gross Assumption

The NTG IDs “NonRes-sAll-MLtgLED-Deemed” and “Res-sAll-MLtgLED-Deemed” expired on 6/30/2017, and are now replaced by “NonRes-sAll-mLEDSpcl” and “Res-sAll-mLEDSpcl” respectively as per DEER Preliminary Review database’s Support table for NTG⁸. The table below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 4 Net-to-Gross Ratios

| NTGR ID | Description | Sector | BldgType | Delivery Method | NTGR |
|----------------------|--|--------|----------|-----------------|------|
| NonRes-sAll-mLEDSpcl | All nonresidential specialty LED lamps (other than A-lamp and screw-in reflector) | NonRes | Any | Any | 0.6 |
| Res-sAll-mLEDSpcl | All residential specialty LED lamps (other than A-lamp and screw-in reflector) | Res | Any | Any | 0.6 |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | Any | Any | 0.55 |

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 |
|-------------|---|--------|----------|-------------|-----------|
| Com-LED-PGE | Non-Res LED; Non-Upstream Program; Annual Installation Rate | Com | Any | NonUpStrm | 1 |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

Effective Useful Life (EUL)

The accepted LED lamp hour is 20,000 hours. The defined annual operating hours vary by building type and as a result so do the effective useful lives. The work paper max EUL for residential applications is 16 years, and 12 years in commercial applications. The EUL is calculated using the following equation, where 16 years is the maximum life.

$$\text{EUL} = (\text{Rated Life of Lamp (20,000 hrs)}) / (\text{Annual Operating Hours for Building Type})$$

Table 6 Effective Useful Life

| EUL ID | Description | Sector | UseCategory | EUL (Years) | RUL (Years) |
|----------------------|---------------------------------|--------|-------------|-------------|-------------|
| ILtg-Res-LED-50000hr | LED lamp - Indoor - Residential | Res | Lighting | 16 | 5.33 |
| ILtg-Com-LED-50000hr | LED Lamp - Indoor- Commercial | Com | Lighting | Varies | Varies |

1.4.2 Codes & Standards Requirements Base Case and Measure Information

Title 20: These measures do not fall under Title 20 of the California Energy Regulations.

Title 24: These measures do fall under Title 24 of the California Energy Regulations. Under this regulation, the following is required:

Title 24 2013 [355] Section 150.0(k)1 contains codes related to Residential lighting which includes a minimum 50 percent of total rated wattage in kitchen to be high efficacy, and non-high efficacy lighting to be controlled by vacancy sensors in certain areas for new construction. The measures in this work paper for Residential building types are not affected by this code.

Title 24 2013 Section 141.0(b)2 contains codes related to Nonresidential lighting as shown below. The measures in this work paper do change the light source in a luminaire and replace the optical system of a luminaire, which triggers Modifications-in-Place. Triggering Modifications-in-Place requires mandatory control provisions in Section 130.1(a)(b)(c)(d) for each enclosed space that includes Area, Shut-off, Multi-level, and if applicable, Daylighting Controls.

Lighting System Alterations shall meet the applicable requirements in TABLE 141.0-E and the following:

- a. Lighting System Alterations include alterations where an existing lighting system is modified, luminaires are replaced, or luminaires are disconnected from the circuit, removed and reinstalled, whether in the same location or installed elsewhere.

EXCEPTION 1 to Section 141.0(b)2Iii: Alterations that qualify as a Luminaire Modification-in-Place.

EXCEPTION 2 to Section 141.0(b)2Iii: Portable luminaires, luminaires affixed to moveable partitions, and lighting excluded in accordance to Section 140.6(a)3.

Luminaire Modifications-in-Place shall meet the applicable requirements in TABLE 141.0-F and the following:

- a. To qualify as a Luminaire Modification-in-Place, luminaires shall only be modified by one or more of the following methods:
 1. Replacing lamps and ballasts with like type or quantity in a manner that preserves the original luminaire listing.
 2. Changing the number or type of light source in a luminaire including: socket renewal, removal or relocation of sockets or lamp holders, and/or related wiring internal to the luminaire including the addition of safety disconnecting devices.
 3. Changing the optical system of a luminaire in part or in whole.
 4. Replacement of whole luminaires one for one in which the only electrical modification involves disconnecting the existing luminaire and reconnecting the replacement luminaire.
- b. Luminaire Modifications-In-Place shall include only alterations to lighting system meeting the following conditions:
 1. Luminaire Modifications-in-Place shall not be part of or the result of any general remodeling or renovation of the enclosed space in which they are located.
 2. Luminaire Modifications-in-Place shall not cause, be the result of, or involve any changes to the panelboard or branch circuit wiring, including line voltage switches, relays, contactors, dimmers and other control devices, providing power to the lighting system.

EXCEPTION to Section 141.0(b)2Iiii2. Circuit modifications strictly limited to the addition of occupancy or vacancy sensors and class two lighting controls are permitted for Luminaire Modifications-in-Place

Federal Standards: These measures do not fall under Federal DOE or EPA Energy Regulations.

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

Since there is uncertainty regarding manufacturer's claims of LED efficiency, this work paper draws from the Commercially Available LED Product Evaluation and Reporting (CALiPER) Program of the U.S. Department of Energy. The CALiPER reports provide not only objective product testing following the IES LM-79 method⁹ and a comparison against manufacturers' published photometric data, but also energy performance data from base case and measure case equipment mounted in insulated recessed cans; this gonio photometric data is valuable as a true reflection of luminaire efficacy *in situ*.

The original edition of this work paper followed the model established by the PG&E "Compact Fluorescent Reflector Lamp" work paper,¹⁰ therefore identifying the American Council for an Energy-Efficient Economy study *Analysis of Standards Options for BR, ER, and R20 Incandescent Lamps*¹¹ as providing relevant technical, economic, market, and infrastructure standards on current reflector lamp equipment. Other studies cited in the original analysis included SERA's *Revised / Updated EULs Based on Retention and Persistence Studies Results* and KEMA's *Illuminating Current CFL Usage Patterns: Results from a CFL Metering Study*.^{12, 13}

In 2009, the market penetration of MR16 LED replacement lamps was 1.7%. The market penetration of LED replacements for PAR, BR, and R shaped lamps was 0.2%. Indoor general illumination applications have the potential to save substantial amounts of electricity.

Delta wattage Assumption (ΔW): In CALiPER Rounds 12 and 14, LED downlights were benchmarked against incandescent equivalents. CALiPER Round 14 states, “The [LED] products were between 527 and 803 lumens and are roughly comparable to 60 to 100 W incandescent downlights.” The tested LED products ranged in power draw from 10 W, comparable to 60 W incandescent, up to approximately 15 W, comparable to a 100 W incandescent downlight fixture. The base case and measure case fixture wattages for this work paper were established based on the CALiPER results, and conservatively selected as 15 W LED replacing a 95 W incandescent and a 10 W LED replacing a 60 W incandescent.

The CALiPER Program’s photometric testing was considered when employing manufacturer’s claims of luminaire efficacy.¹⁴ The CALiPER results correlate the efficacy of integrated LED luminaires to the lumen output and power draw ratings claimed in the manufacturers’ specifications; this work paper assumes similar authenticity from other current integrated LED luminaires (complete retrofit) solutions. A relative reduction in lumen output is factored into the measure case selections. Case studies¹⁵ have proven maintained minimum illumination levels, greater uniformity, and customer acceptance with LED replacements; these are assumed as inherent factors of this retrofit.

Categories of replacement fixtures were established due to variation in power consumption and lumen output as reported in the CALiPER results. The categories are labeled as first, second, and third tier in the table below. Fixture efficacy on average is reported as being higher in the ENERGY STAR qualified product list as compared to the CALiPER reports. For example, ENERGY STAR reported efficacy was 59 lm/W for the first tier, 56 lm/W for the second tier, and 51 lm/W for the third tier. CALiPER reported efficacy was 27 lm/W for the first tier, 54 lm/W for the second tier, and 47 lm/W for the third tier. To be conservative, the CALiPER reports were used as the basis for determining LED replacements.

Table 7 Comparison of Base Case and Measure Case Efficacy

| | Light Source | Category | CALi- PER Round | CALi- PER Refer- ence # | Power (W) | Initial Light Output (lm) | Initial Efficacy (lm/W) | CCT (K) | CRI | Power Factor | Base Case Wattage Range |
|--------------------|--------------|--|-----------------------|----------------------------------|--------------|------------------------------------|-------------------------------|------------|-----|-----------------|-------------------------------|
| First Tier | | | | | | | | | | | |
| Base Case | Incandescent | Replacement Lamp (R20) Incandescent | 8 | 09-05 | 40 | 227 | 6 | 2,516 | 99 | 0.99 | Up to 40 W |
| | Incandescent | Replacement Lamp (R16) Incandescent | 8 | 09-08 | 40 | 233 | 6 | 2,529 | 100 | 1 | |
| Average | | | | | 40 | 230 | 6 | 2,523 | 100 | 1.00 | |
| Measure Case | SSL* | Downlight (Track-spot) | 12 | 10-40 | 9 | 249 | 26 | 2,723 | 79 | 0.8 | Up to 40 W |
| | SSL* | Downlight (Track-spot) | 12 | 10-43 | 9 | 309 | 36 | 3,028 | 81 | 0.98 | |
| | SSL | Downlight (Track-spot) | 12 | 10-57 | 5 | 136 | 25 | 2,996 | 93 | 0.53 | |
| | SSL | Downlight (Track-spot) | 8 | 09-33 | 9 | 204 | 22 | 2,557 | 83 | 0.8 | |
| Average | | | | | 8.0 | 225 | 27 | 2,826 | 84 | 0.78 | |
| Second Tier | | | | | | | | | | | |
| Base Case | Incandescent | Replacement Lamp (A-lamp) Incandescent | 11 | 10-31 | 61 | 823 | 14 | 2,771 | 100 | 1 | 41 W to 65 W |
| | Incandescent | Replacement Lamp (A-lamp) Incandescent | 6 | 08-49 | 61 | 739 | 12 | 2,703 | 100 | 1 | |

Table 7 Comparison of Base Case and Measure Case Efficacy

| | Light Source | Category | CALi- PER Round | CALi- PER Refer- ence # | Power (W) | Initial Light Output (lm) | Initial Efficacy (lm/W) | CCT (K) | CRI | Power Factor | Base Case Wattage Range |
|---------|--------------|--|-----------------------|----------------------------------|--------------|------------------------------------|-------------------------------|------------|-----|-----------------|-------------------------------|
| | Incandescent | Outdoor Wall Incandescent | 6 | 08-59 | 60 | 386 | 6 | 2,700 | 99 | 1 | |
| | Incandescent | Replacement Lamp (A-lamp) Incandescent | 5 | 08-04 | 55 | 353 | 7 | 2,491 | 99 | 1 | |
| | Incandescent | Replacement Lamp (R30) Incandescent | 5 | 08-13 | 65 | 732 | 11 | 2,681 | 99 | 1 | |
| Average | | | | | 60.4 | 607 | 10 | 2,669 | 99 | 1.0 | |

| | | | | | | | | | | | |
|-----------------|------|------------------------------------|----|--------|------|-----|----|-------|----|------|-----------------|
| Measure Case | SSL | Downlight (6" retrofit) | 14 | 11-64 | 10 | 694 | 69 | 3,046 | 84 | 0.84 | 41 W to 65 W |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-64i | 10 | 689 | 69 | | | 0.84 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-82 | 11 | 589 | 54 | 3,029 | 84 | 0.88 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-82i | 11 | 542 | 49 | | | 0.87 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-98 | 12 | 629 | 53 | 3,006 | 83 | 0.97 | |
| | SSL | Downlight (6" recessed) | 12 | 10-38 | 10 | 596 | 58 | 2,776 | 93 | 0.87 | |
| | SSL* | Downlight (Track-spot) | 12 | 10-40 | 9 | 249 | 26 | 2,723 | 79 | 0.8 | |
| | SSL | Downlight (6" recessed) | 12 | 10-41 | 12 | 935 | 75 | 2,729 | 91 | 0.97 | |
| | SSL* | Downlight (Track-spot) | 12 | 10-43 | 9 | 309 | 36 | 3,028 | 81 | 0.98 | |
| Average | | | | | 10.4 | 581 | 54 | 2,905 | 85 | 0.9 | |

Third Tier

| | | | | | | | | | | | |
|--------------|--------------|--|----|-------|------|-------|----|-------|-----|--|------------------|
| Base Case | Incandescent | Replacement Lamp (A-lamp) Incandescent | 12 | 11-12 | 99 | 1,322 | 13 | 2,871 | 100 | | 66 W to 100 W |
| | Incandescent | Replacement Lamp (A-lamp) Incandescent | 12 | 11-25 | 90 | 1,245 | 14 | 2,764 | 100 | | |
| Average | | | | | 94.5 | 1,284 | 14 | 2,818 | 100 | | |

| | | | | | | | | | | | |
|-----------------|-----|------------------------------------|----|--------|----|-----|----|-------|----|------|------------------|
| Measure Case | SSL | Downlight (6" retrofit) | 14 | 11-63 | 14 | 576 | 40 | 3,174 | 81 | 0.94 | 66 W to 100 W |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-63i | 14 | 562 | 40 | | | 0.94 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-73 | 14 | 817 | 58 | 3,196 | 78 | 0.92 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-73i | 14 | 803 | 57 | | | 0.92 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-74 | 14 | 614 | 44 | 3,007 | 80 | 0.95 | |

Table 7 Comparison of Base Case and Measure Case Efficacy

| | Light Source | Category | CALi- PER Round | CALi- PER Refer- ence # | Power (W) | Initial Light Output (lm) | Initial Efficacy (lm/W) | CCT (K) | CRI | Power Factor | Base Case Wattage Range |
|---------|--------------|------------------------------------|-----------------------|----------------------------------|--------------|------------------------------------|-------------------------------|------------|-----|-----------------|-------------------------------|
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-74i | 14 | 563 | 42 | | | 0.96 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-75 | 15 | 801 | 55 | 3,073 | 82 | 0.98 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-75i | 15 | 786 | 54 | | | 0.98 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-76 | 14 | 568 | 41 | 3,172 | 82 | 0.91 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-76i | 14 | 541 | 40 | | | 0.91 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-96 | 14 | 619 | 45 | 3,083 | 81 | 0.98 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-96i | 14 | 591 | 44 | | | 0.98 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-97 | 14 | 577 | 42 | 2,925 | 81 | 0.94 | |
| | SSL | Downlight (6" retrofit) | 14 | 11-103 | 14 | 768 | 55 | 2,762 | 80 | 0.8 | |
| | SSL | Downlight (6" retrofit in situ) | 14 | 11-103i | 14 | 769 | 55 | | | 0.8 | |
| | SSL | Downlight (6" recessed) | 14 | 11-104 | 17 | 962 | 55 | 2,946 | 77 | 0.99 | |
| | SSL | Downlight (4" recessed) | 12 | 10-49 | 18 | 874 | 48 | 2,967 | 78 | 0.98 | |
| | SSL | Downlight (5" recessed) | 12 | 10-50 | 17 | 699 | 41 | 3,028 | 82 | 0.98 | |
| | SSL | Downlight (6" recessed) | 12 | 10-53 | 24 | 1,072 | 44 | 2,995 | 84 | 0.98 | |
| | SSL | Downlight (Track-spot) | 12 | 10-56 | 21 | 946 | 45 | 3,045 | 84 | 0.99 | |
| | SSL | Downlight (Track-spot) | 12 | 11-02 | 15 | 643 | 44 | 3,193 | 81 | 0.97 | |
| | SSL | Downlight (Track-spot) | 12 | 11-07 | 13 | 571 | 45 | 3,392 | 91 | 0.99 | |
| Average | | | | | 15.3 | 715 | 47 | 3,064 | 81 | 0.9 | |

*Suitable for first and second tier.

Section 2. Calculation Methods

2.1 Electric Energy Savings Estimation Methodologies

Energy savings vary by market sector (building type) because of differences in operating hours and interactive effect multipliers. The operating hours and interactive effects factor for each segment were taken from DEER data.

$$\text{Annual Electric Savings (kWh/fixture)} = \frac{\Delta \text{Watts} \times (\text{Annual Hours of Use}) \times \text{kWh Interactive Effects Factor}}{1000}$$

$$\Delta \text{Watts} = (\text{Measure Case Wattage} * \text{WRR}) - \text{Measure Case Wattage}$$

The following example calculation demonstrates the annual energy savings, kWh, for the Assembly building type (ASM), for the LD127 'LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install < 7W LED' measure:

$$\text{Annual Electric Savings (kWh/fixture)} = \frac{(3 * 2.42 - 3) \times 1,160 \times 1.04}{1000} = 5.14$$

2.2. Demand Reduction Estimation Methodologies

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

$$\text{Demand Savings (kW/fixture)} = \frac{\Delta \text{Watts} \times \text{kW Interactive Effects Factor} \times \text{CDF}}{1000}$$

The following example calculation demonstrates the peak demand reduction, kW, for the Assembly building type (ASM), for the LD127 'LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install < 7 W LED' measure:

$$\text{Demand Savings (kW/fixture)} = \frac{(3 * 2.42 - 3) \times 1.18 \times 0.221}{1000} = 0.0011$$

2.3. Gas Energy Savings Estimation Methodologies

DEER 2011 included an analysis of the thermal interactive effects of lighting measures. The energy savings achieved via a reduction in lighting demand is partially offset by an increase in thermal energy needed for heating.

$$\text{Gas Savings (therms/fixture)} = \frac{(\Delta \text{Watts/unit}) \times (\text{Annual Hours of Use}) \times \text{Gas Interactive Effects Factor}}{1,000}$$

The following example calculation demonstrates the natural gas savings, therms, for the Assembly building type (ASM), for the LD127 'LED Surface, Pendant, Track, Accent, and Recessed Downlight: Install < 7 W LED' measure:

$$\text{Gas Savings (therms/fixture)} = \frac{(3 * 2.42 - 3) \times (1,160) \times -0.0099}{1,000} = -0.049$$

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 base case load shape would be expected to follow a typical residential lighting end use load shape.

3.2 Measure Load Shapes

For purposes of the net benefits estimates in the E3 calculator, what is required is the load shape that ideally represents the *difference* between the base equipment and the installed energy efficiency measure. This *difference* load profile is what is called the Measure Load Shape and would be the preferred load shape for use in the net benefits calculations.

The measure load shape for this measure is determined by the E3 calculator based on the applicable residential market sector and the lighting end-use.

Table 8 Building Types and Load Shapes

| Building Type | Load Shape | E3 Alternate Building Type |
|-----------------|-----------------------------|----------------------------|
| All Commercial | PGE:DEER:Com:Indoor_CFL_Ltg | NON_RES |
| All Residential | PGE:DEER:Indoor_CFL_Ltg | RES |

Section 4. Base Case & Measure Costs

A joint effort was made between SCE and PG&E to update base case and measure costs for DEER 2016 affected measures.

4.1 Base Case(s) Costs

The base case costs are split into 60% CFL and 40% non CFL, as per Navigant LED Study¹⁶. The technique of web scraping (aka web harvesting, web crawling, web data extraction) was used to gather pricing information from the Home Depot website for base case costs. The methodology used for measure costs applies to base case costs. See Section 4.2 for the methodology. The base case costs are reduced by 30% as suggested by the Navigant LED Study. The 30% reduction factor is “to account for the difference between online and typical purchase price” (page 1-3).

4.2 Measure Costs

The technique of web scraping was used to gather pricing information from the Home Depot website for measure case costs. First, a small sample of products was examined between different online retailers to determine the need to include items from various retailers and the discrepancy between pricing. Please refer to the Competitive Pricing tab in the cost spreadsheet. Due to the competitive pricing of the same fixture from different retailers, only Home Depot data was examined in detail.

A manual process of examining reasonable cost was conducted by viewing the scatterplot of all costs and its associated rated wattages and categorizing the items into a high, medium, or low cost bin. Note that in some cases where enough data was scraped, only Energy Star lamps and fixtures were considered in the measure case and CA Title 20 compliant lamps and fixtures were considered in the base case.

Item descriptions were also viewed to understand the reasoning of such high costs. It was almost always found that items with high costs were associated with architectural features and/or specialty finishes. As a result, items that fell into the high cost category was not used in the calculations of cost for the work papers because it does not appropriately reflect the approach most consumers would take to implement energy efficiency projects. Refer to the cost spreadsheet for detailed information. Furthermore, the latest EM&V Study from Navigant for LED costs uses the 25th percentile for the median price.

Using the low and medium cost data from Home Depot, the best-fit line or linear regression was used to determine the association between fixture wattages and cost. Please see the cost spreadsheet for the specific linear regression equation generated for the low cost and medium cost. Raw data points are also included in the spreadsheet.

For work paper purposes, the costs are an equal representation of the medium and low cost categories. Therefore, the best representative association is the average of the trend line for medium cost and the trend line of the low cost. This process is not the same as a linear regression determined from the low and medium cost items combined. Due to the quantity in the data sampling, the items associated with the low or medium cost would influence the linear regression. For this reason, the best representative cost comes from the average of the linear regression from the medium cost and the linear regression from the cost. This is how cost is propagated for all the technology categories.

As with base case costs, the measure costs are also reduced by 30% to account for the bulk wholesale pricing discrepancy.

4.3 Incremental & Full Measure Costs

Table 9 Full and Incremental Measure Cost Equations

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

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

4.3.1 Full Measure Cost

Full Measure Cost is the cost to install an energy efficient measure per the CPUC calculators. This definition implies a different meaning depending on the Measure Application type.

The Full measure cost is used for Direct Install Measures and New Construction. A labor cost of \$36.13 is used based on WO017¹⁷. It is estimated a half hour for installation, using the \$72.26 labor rate from WO017. For full measure costs please refer to the LED fixture cost spreadsheet.

4.3.2 Incremental Measure Costs

The labor required installing base case or measure case is equivalent. Therefore, labor cost is not considered in incremental measure costs. For incremental measure costs please refer to the LED fixture cost spreadsheet.

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- ³ Navigant Consulting. *Energy Savings Potential of Solid-State Lighting in General Illumination Applications*. For the U.S. Department of Energy. January 2012. http://www1.eere.energy.gov/buildings/ssl/tech_reports.html
- ⁴ DOE Solid-State Lighting CALiPER Program. *Application Summary Report 14* (March 2012)—downlight retrofit units. <http://www1.eere.energy.gov/buildings/ssl/reports.html>
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- ⁷ The DEER Measure Cost Data Users Guide found on www.deeresources.com under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata_format-V0.97.xls*.
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- ¹² Skumatz Economic Research Associates. *Revised / Updated EULs Based on Retention and Persistence Studies Results*. Revised Report, July 8, 2005.
- ¹³ KEMA. *Illuminating Current CFL Usage Patterns: Results From a CFL Metering Study*. For the San Diego Gas & Electric Company. 2003.
- ¹⁴ In addition to CALiPER Round 12 (June 2011) and Round 14 (March 2012), every round from Round 1 (March 2007) through Round 9 (October 2009) included downlights. Detailed reports for 58 downlights (as of June 15, 2012) are available at <http://www1.eere.energy.gov/buildings/ssl/caliper/default.aspx>
- ¹⁵ DOE GATEWAY Demonstration. *Demonstration Assessment of LED Retrofit Lamps: Malibu, Cal.* (March 2012) 12 W LED PAR 38 lamps replaced 60W halogen PAR 38 flood lamps in an art museum.
———. *Demonstration Assessment of LED Retrofit Lamps: Eugene, Oregon* (September 2011) 12 W LED PAR 38 lamps replaced 90 W PAR 38 130 V narrow flood lamps in an art museum.

- . *Demonstration Assessment of LED Retrofit Lamps: Portland, Oregon* (July 2011)
12 W LED lamps replaced 15 W and 23 W reflectorized CFL track lights used to illuminate artwork.
- . *Demonstration Assessment of LED Retrofit Lamps: San Francisco, Cal.* (Nov. 2010; Updated Jan. 2012)
6 W LED MR-16 and 11 W LED PAR 30 lamps replaced halogen wall-grazing luminaires, track lights, and recessed downlights in a hotel.
- . *Demonstration Assessment of LED Museum Accent Lighting: Chicago, Illinois* (November 2010)
An LED track system replaced halogen track luminaires in a science museum.
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http://www1.eere.energy.gov/buildings/ssl/gatewaydemos_results.html

¹⁶ California LED Workpaper Update Study, Submitted by Navigant Consulting, Inc., August 28, 2015

¹⁷ 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014.