

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

**Pacific Gas & Electric Company**  

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**Customer Energy Solutions**

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

Measure Codes: LD127-LD146

**08/10/2017**

## At-A-Glance Summary

<b>Applicable Measure Codes:</b>	<b>LD127-LD146</b>															
<b>Measure Description:</b>	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.															
<b>Energy Impact Common Units:</b>	Fixture.															
<b>Base Case Description:</b>	Various: Refer to .xlsx file attached Source: Energy Division ,WRR Lighting LED Disposition – July, 2016															
<b>Base Case Energy Consumption:</b>	Various: ED LED Fixture wattage reduction ratio, Refer to .xlsx file attached Source: Energy Division ,WRR Lighting LED Disposition – July, 2016															
<b>Measure Energy Consumption:</b>	Various: Refer to .xlsx file attached Source: PG&E Calculations															
<b>Energy Savings (Base Case – Measure)</b>	Various: Refer to .xlsx file attached Source: PG&E Calculations															
<b>Costs Common Units:</b>	\$ per fixture.															
<b>Base Case Equipment Cost (\$/unit):</b>	Various: Refer to .xlsx file attached  Source: PG&E Calculations.															
<b>Measure Equipment Cost (\$/unit):</b>	Various: Refer to .xlsx file attached Source: PG&E Calculations.															
<b>Measure Incremental Cost (\$/unit):</b>	Various: Refer to .xlsx file attached Source: PG&E Calculations.															
<b>Effective Useful Life (years):</b>	ILtg-Res-LED-50000hr, 16 years ILtg-Com-LED-50000hr, Varies Source: DEER 2016															
<b>Program Type:</b>	ROB or NC															
<b>Net-to-Gross Ratios:</b>	<table border="1"> <thead> <tr> <th>NTGR ID</th> <th>NTGR</th> <th>Source</th> </tr> </thead> <tbody> <tr> <td>NonRes-sAll-mLEDSpcl</td> <td>0.6</td> <td>Preliminary Ex Ante database<sup>1</sup></td> </tr> <tr> <td>Res-sAll-mLEDSpcl</td> <td>0.6</td> <td>Preliminary Ex Ante database</td> </tr> <tr> <td>Com-Default&gt;2yrs</td> <td>0.6</td> <td>DEER 2016</td> </tr> <tr> <td>Res-Default&gt;2</td> <td>0.55</td> <td>DEER 2016</td> </tr> </tbody> </table>	NTGR ID	NTGR	Source	NonRes-sAll-mLEDSpcl	0.6	Preliminary Ex Ante database <sup>1</sup>	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 <sup>1</sup>														
Res-sAll-mLEDSpcl	0.6	Preliminary Ex Ante database														
Com-Default>2yrs	0.6	DEER 2016														
Res-Default>2	0.55	DEER 2016														
<b>Important Comments:</b>	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 method<sup>2</sup> 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**

<b>Delivery Type</b>	<b>Applicable Building Types</b>	<b>Application Type</b>
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.<sup>3</sup> 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.<sup>4</sup>

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.<sup>5</sup>

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.<sup>6</sup> 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](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 3 Measure Application Type<sup>7</sup>**

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 ( $\Delta W$ )

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 NTG<sup>8</sup>. 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	GSIA Value
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.

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

**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 method<sup>9</sup> 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,<sup>10</sup> therefore identifying the American Council for an Energy-Efficient Economy study *Analysis of Standards Options for BR, ER, and R20 Incandescent Lamps*<sup>11</sup> 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*.<sup>12, 13</sup>

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 ( $\Delta W$ ):** 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.<sup>14</sup> 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 studies<sup>15</sup> 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
<i>First Tier</i>											
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	
<i>Second Tier</i>											
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 < 7 W 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**

<b>Building Type</b>	<b>Load Shape</b>	<b>E3 Alternate Building Type</b>
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 Study<sup>16</sup>. 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 25<sup>th</sup> 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 <sup>st</sup> Baseline	2 <sup>nd</sup> 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 WO017<sup>17</sup>. 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.

## References

- <sup>1</sup> <http://deeresources.com/index.php/ex-ante-database/best-practices-database>
- <sup>2</sup> ASTM International. *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*. ASTM E283 - 04(2012). <http://www.astm.org/Standards/E283.htm>
- <sup>3</sup> 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](http://www1.eere.energy.gov/buildings/ssl/tech_reports.html)
- <sup>4</sup> DOE Solid-State Lighting CALiPER Program. *Application Summary Report 14* (March 2012)—downlight retrofit units. <http://www1.eere.energy.gov/buildings/ssl/reports.html>
- <sup>5</sup> Navigant Consulting. *Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications*. For the U.S. Department of Energy. January 2011. [http://www1.eere.energy.gov/buildings/ssl/tech\\_reports.html](http://www1.eere.energy.gov/buildings/ssl/tech_reports.html)
- <sup>6</sup> DOE Solid-State Lighting CALiPER Program. *Round 12 Summary Report* (June 2011)—includes recessed downlight luminaires, track light luminaires, cove lighting luminaires, and other applications. <http://www1.eere.energy.gov/buildings/ssl/reports.html>  
———. *Application Summary Report 14* (March 2012)—downlight retrofit units. <http://www1.eere.energy.gov/buildings/ssl/reports.html>
- <sup>7</sup> 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*.
- <sup>8</sup> <http://deeresources.com/index.php/ex-ante-database/best-practices-database>
- <sup>9</sup> Illuminating Engineering Society. *Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products*. IES LM-79-08. 2008. <http://www.ies.org/store/product/approved-method-electrical-and-photometric-measurements-of-solidstate-lighting-products-1095.cfm>
- <sup>10</sup> Pacific Gas and Electric Company. *Compact Fluorescent Reflector Lamp (CFRL)*. Work Paper PGECOLTG103. June 2007.
- <sup>11</sup> American Council for an Energy-Efficient Economy. Energy Solutions. *Analysis of Standards Options for BR, ER, and R20 Incandescent Lamps*. For the Pacific Gas and Electric Company. April 28, 2004. [http://www.energy.ca.gov/appliances/2004rulemaking/documents/case\\_studies/CASE\\_BR\\_Lamps.pdf](http://www.energy.ca.gov/appliances/2004rulemaking/documents/case_studies/CASE_BR_Lamps.pdf)
- <sup>12</sup> Skumatz Economic Research Associates. *Revised / Updated EULs Based on Retention and Persistence Studies Results*. Revised Report, July 8, 2005.
- <sup>13</sup> KEMA. *Illuminating Current CFL Usage Patterns: Results From a CFL Metering Study*. For the San Diego Gas & Electric Company. 2003.
- <sup>14</sup> 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>
- <sup>15</sup> 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.
- . *Demonstration Assessment of LED Residential Downlights and Undercabinet Lights: 2008 Eugene Tour of Homes*. LED lighting was installed in showcase homes.  
[http://www1.eere.energy.gov/buildings/ssl/gatewaydemos\\_results.html](http://www1.eere.energy.gov/buildings/ssl/gatewaydemos_results.html)

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

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