Work Paper PGECOLTG163
LED Candelabra Replacements
Revision 6

Pacific Gas & Electric Company

Customer Energy Solutions

LED Candelabra Replacements

Measure Codes L042, L043, LC108

06/29/2017

At-A-Glance Summary

Applicable Measure Codes:	L042 (Res/Com)	L043 (MFM)	LC108 (Res/Com)	LC108 (MFM)
Measure Description:	LED Candelabra <3W	LED Candelabra <3W	LED Candelabra ≥3 to ≤5	LED Candelabra ≥3 to ≤5
Energy Impact Common Units:	Lamp.			
Base Case Description:	7.35 Wattage Reduction Ratio, Source: DEER 2016 methodology			
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 lamp			
Base Case Equipment Cost ($/unit):	Refer to .xlsx file attached. Source: IOU consistent Cost Table			
Measure Equipment Cost ($/unit):	Refer to .xlsx file attached Source: IOU consistent Cost Table			
Gross Measure Cost ($/unit)	Refer to .xlsx file attached, Source: IOU consistent Cost Table			
Measure Incremental Cost ($/unit):	Refer to .xlsx file attached, Source: IOU consistent Cost Table			
Effective Useful Life (years):	Various. Refer to .xlsx file attached Source: PG&E Calculations.			
Program Type:	ROB			
Net-to-Gross Ratios:	**NTGR ID** / **Sector** / **NTGR** NonRes-sAll-mLEDSpcl / NonRes / 0.6 Res-sAll-mLEDSpcl / Com / 0.6 Source: DEER 2017			
Important Comments:				

Document Revision History

Revision #	Date	Section by Section Description of Revisions	Author (Company)
Revision 0	2/2/2012	PGECOLTG163 R0 LED Candleabra.doc Revised draft per PG&E comments	Marc Theobald (EMCOR Energy Services), Reviewed by Alina Zohrabian (PG&E)
Revision 1	2/2/2012	PGECOLTG163 R1 LED Candleabra.doc Revised based on Energy Division workpaper disposition for Integral LED replacement lamps (May 14-2012)	Alina Zohrabian (PG&E)
Revision 1	8/29/12	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 2	7/13/13	Revised Savings values per ED Workpaper Disposition for Lighting Retrofit, issue March, 2013. For updated savings values, see file PGECOLTG163 R2-Calcs.xlsx For measure L042 PG&E used 2 watts for the measure wattage this went down to 1.8 watts. For measure L043 PG&E used 2 watts for the measure wattage this went down to 1.8 watts.	Alina Zohrabian (PG&E)
Revision 3	3/24/14	Added DI values from (PGE3PLTG179) and Revised savings values per ED Workpaper Disposition for lighting Retrofit, December 14, 2013. For updated savings values, see file PGECOLTG163 R3.xlsx	Alina Zohrabian (PG&E)
Revision 4	1/1/2016	Updated NTG, EUL, annual hours of operation, CDF, IE per DEER 2016. Costs have also been updated.	Linda Wan (PG&E)/Alina Zohrabian (PG&E)
Revision 5	11/18/2016	Updated IE per DEER 2017	Mini Damodaran (PG&E)/Alina Zohrabian (PG&E)
Revision 6	06/29/2017	Updated NTG ID based on the 2017ScrewInLampDisposition	Henry Liu (PG&E)

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Section 1. General Measure & Baseline Data

1.1 Product Measure Description & Background

This work paper details the replacement of existing 15 and 25 watt incandescent candelabra lamps with LED candelabra lamps.

Requirements:

- Must replace a 15 or 25 Watt incandescent candelabra lamp

Table 1 Measure Codes and Description

Measure Code	Description
L042	LED Candelabra <3W
L043	LED Candelabra <3W MF
LC108	LED Candelabra ≥3 to ≤5

Program Restrictions and Guidelines

The delivery method is Upstream/Midstream Programs for commercial customers and the Upstream Lighting Program for residential customers. For Multifamily customers, this product is also available through the downstream program.

In support of the transition to the California Energy Commission's Voluntary California Quality Light-Emitting Diode (LED) Lamp Specification (CEC Spec), to qualify for a rebate in the program, the replacement LED lamps must fall into one of the categories shown in the table below. Only lamps that fully meet the CEC Spec will be supported in the Upstream Lighting Program after Dec 1, 2013.

Table 2 Lamp Specification

Residential: Upstream Lighting Program	Residential: Downstream & Direct Install Commercial: Midstream / Upstream & Direct Install
Must meet CEC specification 3.0[1] and Energy Star 2.0[2] and be listed on both Energy Star and Modernized Appliance Efficiency Database System (MAEDBS) databases. The lamps in MAEDBS must be listed on the "State-regulated Light Emitting Diode Lamp" list[3].	Must be on THE ENERGY STAR Qualified Products List.

Terms and Conditions: The customer must be a residential or commercial PG&E electric customer. Multifamily downstream is eligible.

Market Applicability: The customer must be a residential or commercial PG&E electric customer.

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

Table 3 Delivery Method and Applicable Building Types

Delivery Type	Applicable Building Types	Application Type
Upstream	"Com," "Res"	ROB
Direct Install	DEER Building Types	ROB
Downstream	DEER Building Types	ROB

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 successfully replaced other lighting sources and made their way into the market. LED products continue to improve to be able to compete in any application.

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 4 Measure Application Type[4]

Identifies the measure application type in the Measure Implemenation 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.

1.4 Product Base Case and Measure Case Data

The most common base case wattages of the incandescent lamps are 15, 25 40, and 60 watts, based on analysis by EMCOR Energy Services (EES) determining typical replaced candelabra lamps. The base case wattages follow the DEER Wattage Reduction Ratio (WRR) methodology. The measure case is the associated LED wattage.

1.4.1 DEER Base Case and Measure Case Information

The Database for Energy Efficient Resources (DEER) 2016 contains measures for LED candelabra lamps using the WRR method. The base case wattage is calculated using the WRR of 7.35 as recommended by Energy Division. The measure case is the associated LED wattage.

Hours of Operation

The DEER 2017 hours of operation and interactive effects are used for savings calculations.

Net-to-Gross Assumption

The NTG values are from DEER 2016. Table 5 below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 5 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), all delivery mechanisms	NonRes	Any	Any	0.6
Res-sAll-mLEDSpcl	All residential specialty LED lamps (other than A-lamp and screw-in reflector), all delivery mechanisms	Res	Any	Any	0.6

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 values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

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 / Remaining Useful Life
Although the minimum lamp life in Energy Star is 25,000 hours and most products show a lamp life of 25,000 or 35,000 hours, the Energy Division recommended a lamp life of 15,000 hours. Since the effective useful life (EUL) is depended on hours of operation, the EUL varies by building type. The EUL is calculated using the following equation:

EUL = (Rated Life of Lamp (15,000 hours)) / (Average Operating Hours for Building Type)

Table 6 Effective and Remaining Useful Life

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
ILtg-Res-LED-15000hr	LED lamp - Indoor - Residential - small wattage Globe, Any Candle shape	Res	Lighting	16	5.33
ILtg-Com-LED-15000hr	LED Lamp - Indoor- Commercial - Small wattage Globe, Any Candle shape	Com	Lighting	Varies (max 12 years)	Varies

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 Efficiency Regulations.

Title 24: These measures do not fall under Title 24 [2013] Non-Residential Building Energy Efficiency Standards.

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

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

There are relevant CALiPER studies which were stated in the previous version of this workpaper. However this workpaper is following the disposition for integral LED lamp replacement guidelines from Energy Division to calculate the savings. As the LEDs improve and the efficacy increases the wattage reduction ratio methodology should be revisited since it will not be an appropriate method to calculate savings going forward.

1.4.4 Assumptions and Calculations from Other Sources – Base Case and Measure Case

This workpaper follows the Workpaper Disposition for Integral LED Lamp Replacements from the California Public Utilities Commission; Energy Division dated May 14, 2012.

Section 2. Calculation Methods

2.1 Electric Energy Savings Estimation Methodologies

Energy savings vary by market sector and building type because of differences in operating hours and interactive effect multipliers. 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. Refer to the equation below for the energy savings calculation:

$$Energy\ Savings\left[\frac{kWh}{lamp}\right] = (\Delta kW/lamp) \times (Annual\ hours\ of\ operation) \times (Energy\ Interactive\ Effects)$$

$$\Delta kW/lamp = \frac{(Measure\ case\ wattage \times WRR) - Measure\ case\ wattage}{1000}$$

The following example calculation demonstrates the annual energy savings, kWh per year, for the "Res" building type, for a 2W LED candelabra:

$$Annual\ Energy\ Savings\left[\frac{kWh}{lamp}\right] = (0.002 * 7.35 - 0.002) \times (541) \times (1.02) = 7.01$$

2.2. Demand Reduction Estimation Methodologies

Demand reduction varies by market sector and building type due to different HVAC interactive effects and coincident peak demand multipliers for each type of building type. The operating hours, interactive effects, and coincident diversity factors (CDF) for each segment were taken from DEER 2017 data. Below is the equation to calculate demand savings:

$$Demand\ Savings\left[\frac{kW}{lamp}\right] = (\Delta kW/lamp) \times (lightingCoincidentDemand) \times (DemandInteractive\ Effects)$$

The following example calculation demonstrates the annual energy demand savings, kW per year, for the "Res" building type, for a 2W LED candelabra:

$$Demand\ Savings\left[\frac{kW}{lamp}\right] = (0.002 * 7.35 - 0.002) \times (0.044) \times (1.5) = 0.00084$$

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 savings. The equation below calculates the gas savings:

$$Gas\ Savings\ [Therm/lamp - year] = (\Delta kW/lamp) \times (AnnualHoursOfUse) \times (GasInteractive\ Effects)$$

The following example calculation demonstrates the annual gas savings, therms per year, for the "Res" building type, for a 2W LED candelabra:

$$Gas\ Savings\ [Therm/lamp - year] = (0.002 * 7.35 - 0.002) \times (541) \times (-0.0227) = -0.156$$

Section 3. Load Shapes

Load shapes are an important part of the lifecycle 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 lifecycle 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 interior CFL lighting load shape.

3.2 Measure Load Shapes

The measure load shape for this measure is determined based on the applicable residential and commercial market sector and the Lighting end-use. This load shape is different from the base case due to the savings impact of the measures and is shown by the load shapes listed below.

The closest load shape chosen for this measure is the DEER interior CFL lighting load shape.

Table 7 Building Types and Load Shapes

Building Type	Load Shape	E3 Alternate Building Type
All Commercial, "Com," "OTR"	PGE:DEER:Com:Indoor_CFL_Ltg	NON_RES
All Residential, "Res"	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. Please refer to the LED lamp cost workbook for detailed information.

4.1 Base Case Costs

The base case costs are 100% incandescent. Incandescent costs are calculated from WO017[5] workbook. The base case wattages are mapped to individual LED wattages using a table from the Energy Star Calculator.

4.2 Measure Case Costs

Most costs for LED lamps were provided by Navigant as part of a study on LEDs. Several were interpolated or extrapolated from the Navigant data. The California LED Workpaper Update Study[6] recommends using 25 percentile utilizing CA specific data.

4.3 Incremental & Full Measure Costs

Table 8 Full and Incremental Measure Cost Equations

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

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

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. A labor cost of $5.75 is used from WO017. For full measure costs please refer to the LED lamp 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 lamp cost spreadsheet.

References

[1] CEC Spec v3.0: http://www.energy.ca.gov/business_meetings/2016_packets/2016-12-14/Item_09.pdf

[2] EnergyStar v2.0: https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Lamps%20V2%20Revised%20Spec.pdf

[3] MAEDBS, State-regulated Light Emitting Diode Lamp list, https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx

[4] 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*.

[5] 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014.

[6] California LED Workpaper Update Study. Navigant Consulting. August 28, 2015.