Work Paper PGECOLTG164
LED Globe Lamps
Revision 6

Pacific Gas & Electric Company

Customer Energy Solutions

LED Globe Lamps

Measure Codes L0335, L0336

06/29/2017

At-a-Glance Summary

Applicable Measure Codes:	L0335	L0336
Measure Description:	LED globe: <3 Watts	LED globe: ≥3 to ≤10 Watts
Energy Impact Common Units:	Lamp.	
Base Case Description:	Incandescent globe lamp	
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 ($/lamp):	Various. Refer to .xlsx file attached Source: PG&E Calculations.	
Measure Equipment Cost ($/lamp):	Various. Refer to .xlsx file attached Source: PG&E Calculations.	
Gross Measure Cost ($/lamp)	Various. Refer to .xlsx file attached Source: PG&E Calculations.	
Measure Incremental Cost ($/lamp):	Various. Refer to .xlsx file attached Source: PG&E Calculations.	
Effective Useful Life (years):	Various. Refer to .xlsx file attached Source: DEER 2016	
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	03/05/2012	Original work paper	Daniel Young and Greg Barker (Energy Solutions)
Revision 1	6/8/2012	PGECOLTG164 R1 LEDGlobe.doc Updated for 2013-14	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	7/14/13	Revised Savings values per ED Workpaper Disposition for Lighting Retrofit, issue March, 2013. For updated savings values, see file PGECOLTG164 R2-Calcs.xlsx For measure L0335 PG&E used 2 watts for the measure wattage this went down to 1 watts. For measure L0336 PG&E used 8 watts for the measure wattage this went down to 3 watts.	Alina Zohrabian (PG&E)
Revision 3	3/24/14	Added DI values from (PGE3PLTG180) and Revised savings values per ED Workpaper Disposition for lighting Retrofit, December 14, 2013. For updated savings values, see file PGECOLTG164 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	11/28/2016	Updated Residential Interactive Effect(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 incandescent globe lamps with LED globe lamps.

Requirements:

- Must replace an incandescent globe lamp

Table 1 Measure Codes and Descriptions

Product Code	Description
L0335	LED globe: <3 Watts
L0336	LED globe: ≥3 to ≤10 Watts

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 Specifications

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.

Market Applicability:

Single and Multi-Family Installations and Double-Wide Mobile Homes are eligible.

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 by continuing to improve to be able to compete in any application.

Globe lamps provide omnidirectional light; however, LEDs are inherently directional, and thus have comparatively more difficulty achieving an omnidirectional distribution relative to a directional distribution. LEDs typically outperform incandescent sources by a wider margin in directional applications, such as PAR and MR lamps. However, LED technology is improving quickly, and omnidirectional LED lamps are becoming increasingly available.

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 incandescent globe lamps are 15 and 40 watts. 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 globe lamps using the WRR method. The base case wattage is calculated using the WRR listed in the table below as recommended by Energy Division. The measure case is the associated LED wattage.

Table 5 Wattage Reduction Ratio

Description	WRR
LED lamps less than 3 watts	7.47
LED lamps equal to or greater than 3 watts	4.94

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. The table below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 6 Net-to-Gross Ratios

NTGR ID	Description	Sector	BldgType	Delivery Method	NTGR
NonRes-sAll-	All nonresidential specialty LED lamps	NonRe	Any	Any	0.6

mLEDSpcl	(other than A-lamp and screw-in reflector), all delivery mechanisms	s			
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 for LED lamps less than 3 watts and 20,000 hours for LED lamps greater than or equal to 3 watts. Since the effective useful life (EUL) is dependent on the hours of operation, the EUL varies by building type. The EUL is calculated using the following equation:

EUL = (Rated Life of Lamp (15,000 or 20,000 hours)) / (Average Operating Hours for Building Type)

Table 7 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-Res-LED-20000hr	LED lamp - Indoor - Residential	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
ILtg-Com-LED-20000hr	LED Lamp - Indoor- Commercial	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 Regulations.
Title 24: These measures do not fall under Title 24 [2013] of the California Energy Regulations.
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

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 LED lamps 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 and Measure Cases

This workpaper follows the LED-WRR-Workpaper Disposition from the California Public Utilities Commission; Energy Division dated July 22, 2016.

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 Globe:

$$Energy\ Savings\left[\frac{kWh}{lamp}\right] = (0.002 \times 7.47 - 0.002) \times (541) \times (1.02) = 7.14$$

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:

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

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

$$Demand\ Savings\left[\frac{kW}{lamp}\right] = (0.002 \times 7.47 - 0.002) \times (0.044) \times (1.5) = 0.00085$$

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:

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

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

$$Gas\ Savings\ [Therm/lamp] = (0.002 \times 7.47 - 0.002) \times (541) \times (-0.0227) = 0.1589$$

Section 3. Load Shapes

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure's load shape. The measure's load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure's Total Resource Cost (TRC) benefit.

3.1 Base Case Load Shapes

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

3.2 Measure Load Shapes

The measure load shape for this measure is determined based on the applicable residential, commercial, or multifamily 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 8 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(s) 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 9 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 $3.61 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.