

**Work Paper PGECOLTG177
LED BR-R Lamps
Revision 5**

Pacific Gas & Electric Company
Customer Energy Solutions

LED BR/R Lamps

Measure Codes L1071, L1072, L1073

6/7/2017

At-a-Glance Summary

Applicable Measure Codes:	L1071	L1072	L1073						
Measure Description:	LED R-BR: <11 Watts	LED R-BR: 11 to <14 Watts	LED R-BR: 14 to ≤22 Watts						
Energy Impact Common Units:	Lamp.								
Base Case Description:	Incandescent R, BR or ER lamps or CFL R,BR Lamps Source: Energy Star, and PG&E Calculations.								
Base Case Energy Consumption:	Various. Source: PG&E Calculations								
Measure Energy Consumption:	Various. Source: PG&E Calculations.								
Energy Savings (Base Case – Measure)	Various. Source: PG&E Calculations.								
Costs Common Units:	\$ per lamp.								
Base Case Equipment Cost (\$/lamp):	Various.								
Measure Equipment Cost (\$/lamp):	Various.								
Gross Measure Cost (\$/lamp)	Various.								
Measure Incremental Cost (\$/lamp):	Various.								
Effective Useful Life (years):	Various. Source: 2016 DEER								
Program Type:	ROB.								
Net-to-Gross Ratios:	<table border="1"> <thead> <tr> <th>NTGR ID</th> <th>NTGR</th> </tr> </thead> <tbody> <tr> <td>NonRes-sAll-mLEDARefl</td> <td>0.91</td> </tr> <tr> <td>Res-sAll-mLEDARefl</td> <td>0.91</td> </tr> </tbody> </table> <p>Source: 2017 Disposition for Screw-In Lamps</p>			NTGR ID	NTGR	NonRes-sAll-mLEDARefl	0.91	Res-sAll-mLEDARefl	0.91
NTGR ID	NTGR								
NonRes-sAll-mLEDARefl	0.91								
Res-sAll-mLEDARefl	0.91								
Important Comments:									

Document Revision History

Revision #	Date	Section by Section Description of Revisions	Author (Company)
Revision 0	2/26/13	PGECOLTG177 R0 LED BR/R-Lamps.doc Original Workpaper	Alina Zohrabian (PG&E)
Revision 1	9/16/13	PGECOLTG177 R1 LED BR/R-Lamps.doc Created WRR from the original workpaper calculation and applied it to the lowest wattage in the range (based on a direction from a phone conversation with Kevin Madison on 9/12/13.	Alina Zohrabian (PG&E)
Revision 1	10/8/13	PGECOLTG177 R1 LED BR/R-Lamps.doc Revised program description	Alina Zohrabian (PG&E)
Revision 2	5/7/14	PGECOLTG177 R2 LED BR/R-Lamps.doc Added DI values (No original DI workpaper existed) and Revised savings values per ED workpaper Disposition for lighting Retrofit, December 14, 2013. For updated savings values, see file PGECOLTG177 R2.xlsx	Alina Zohrabian (PG&E)
Revision 3	1/1/2016	Updated NTG, GSIA, EUL, annual hours of operation, CDF, and IE per DEER 2016. Base case costs and measure costs have also been updated.	Linda Wan (PG&E)/ Alina Zohrabian (PG&E)
Revision 4	11/28/2016	Updated Residential Interactive Effect(IE) per DEER 2017	Mini Damodaran (PG&E)/ Alina Zohrabian (PG&E)
Revision 5	6/7/2017	Updated WRR, base case percentages and NTG as per 2017 Disposition for Screw-In Lamps; Base costs changed based on base case %; NTG changed to 0.91; Updated Program Restrictions and Guidelines	Alina Zohrabian (PG&E)/ Mini Damodaran (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 or CFL R/BR lamps with LED R/BR lamps.

Requirements:

- Must replace an incandescent or CFL R/BR lamp

Table 1 Measure Codes and Descriptions

Product Code	Description
L1071	LED R-BR: <11 Watts
L1072	LED R-BR: 11 to <14 Watts
L1073	LED R-BR: 14 to ≤22 Watts

Program Restrictions and Guidelines

This workpaper is configured to accommodate any additional program changes to address higher efficacy lamps, if necessary. Currently the lamps rebated through the residential program must meet both Energy Star and the CEC Voluntary California Quality Light-Emitting Diode (LED) Lamp Specification (CEC Spec) requirements. These lamps meet higher quality product performance criteria as defined by CEC. The CEC Spec has added new efficacy requirements.

For lamps rebated through the commercial programs the minimum efficacy requirements have increased due to stricter Energy Star requirements. IOU’s program staff will work with CPUC program staff to make sure all the rebated lamps meet the appropriate program rules and to reach towards the same common goals.

- The delivery method is Upstream/Midstream Programs for commercial customers and the Upstream Lighting Program for residential customers. This workpaper also covers Direct Install delivery channel. 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 non-residential PG&E electric customer.

Market Applicability:

Single and Multi-Family Installations are eligible. These measures include mid and upstream rebates and direct install where noted in the data.

Please refer to the table below for 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” and “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.

The R symbol (short for Reflector) is to indicate that a bulb includes a parabolic or elliptical section below the major diameter designed to have a reflector coating to direct the light beam. The B symbol on the BR (Bulged Reflector) lamp is to indicate a bulb in which the curve making up the major portion of the side of the bulb has a radius greater than one-half the bulb diameter and a center in the plane of maximum diameter. The first number symbol indicates the diameter of the bulb in eighths of an inch. For example, a BR30 lamp has a nominal diameter of 30 eighths of an inch, or 3.75 inches⁴.

R/BR lamps are directional lamps but have a softer distribution and wider beam angles than PAR lamps and are used mostly in residential applications. These lamps come in different size diameters R20/BR/20, R30, BR30LEDs are inherently directional, which makes them well suited for use in lamps intended to replace conventional reflector lamps. Additionally, the optics can be arranged at the LED package level, eliminating the need for reflectors and lenses that shape the beam.

1.3 Measure Application Type

The Database for Energy Efficiency Resources (DEER) developed by the California Public Utilities Commission defines the measure application type. The Support table “Measure Application Type” in the “Measure Catalog” can be found using the latest version of the Remote Ex-Ante Database Interface (READI) on the Database for Energy-Efficient Resources (DEER) website⁵.

Table 4 Measure Application Type

Code	Description	Comment
ROB	Replace on Burnout	<i>Measure technology applied instead of Code/Standard technology at the time of replacement, Single baseline (above code), incremental or full costs</i>
NC	New Construction	<i>Measure technology applied instead of Code/Standard technology during new construction, Single baseline (above code), incremental or full costs</i>
ROBNC	ROB or NC	<i>Measure technology applied instead of Code/Standard technology at the time of replacement or new construction, Single baseline (above code), incremental or full costs</i>

All the measures within this workpaper are ROB.

1.4 Product Base Case and Measure Case Data

1.4.1 DEER Base Case and Measure Case Information

The base case wattage is calculated using the wattage reduction ratio (WRR). WRR is the ratio of the deemed baseline wattage to the deemed LED wattage. Table below shows the approved WRR from July 1st, 2017 based on 2017 "Comprehensive Workpaper Disposition for: Screw-In Lamps" Disposition from the California Public Utilities Commission; Energy Division, dated May16, 2017⁶.

Table 5 Wattage Reduction Ratio

Description	WRR
LED lamps less than 11 watts	5.24
LED lamps between 11-13 watts	4.13
LED lamps equal to or greater than 14 watts	3.73

Hours of Operation

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

Net to Gross Assumption

Table below shows the approved NTG values effective from July 1st, 2017 based on 2017 Disposition for Screw-In Lamps. 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-mLEDARefl	Nonresidential LED A-lamp and screw-in reflector, all delivery mechanisms	NonRes	Any	Any	0.91
Res-sAll-mLEDARefl	Residential LED A-lamp and screw-in reflector, all delivery mechanisms	Res	Any	Any	0.91

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.

Table 7 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 / Remaining Useful Life

Although the EULs for both products are listed as min 25,000 and max 50,000 hours, Energy Division recommended a lamp life of 20,000 hours for LED BR/R Lamps. Since the EUL is dependent on the hours of operation, the EUL varies by building type. The Energy Division also recommended using a maximum value of 12 years for EUL, which is the life of a pin-based CFL fixture in commercial application. For residential application the life of a pin-based CFL fixture is 16 years.

The EUL is based on 20,000 hours approved Lamp life divided by average annual hours of operation for each building type:

$$\text{EUL} = (\text{Lamp Life (20,000 hours)}) / (\text{Average Operating Hours Per Year})$$

Table 8 Effective and Remaining Useful Life

EUL ID	Description	Sector	UseCategory	EUL (Years)	RUL (Years)
ILtg-Res-LED-20000hr	LED lamp - Indoor - Residential	Res	Lighting	16	5.33
ILtg-Com-LED-20000hr	LED Lamp - Indoor-Commercial	Com	Lighting	Varies (max 12)	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] 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

1.4.3.1 CALiPER Application Summary Report 164:

The most recent CALiPER report stated that as of January of 2012, DOE estimated that BR30 lamps made up approximately 38% of the installed base case of PAR, BR, and R lamps, which corresponds to approximately 2.02 million units in the US. Approximately 89% of the products were estimated to be installed in residential applications.

Based on the CALiPER report product selection the BR30/R30 with 65 watts is the most common of all the BR/R lamps especially in residential applications. CALiPER tested a few BR/R lamps in the earlier rounds (4 products in round 2, one product in round 3, and one product in round 9). The test ID RT42 was reported in “retail replacement lamps in April, 2012. CALiPER tested not only for lumen output, input wattage and efficacy, but for CCT (Correlated Color Temperature),CRI (Color Rendering Index), power factor, R9 (Special color rendering index, mostly for red colors), D_{uv} (the distance from Planckian locus on the CIE 1960 chromaticity diagram). Some of the results of the tests are shown in table below.

Table 9 Previous CALiPER Testing of BR30 and R30 LED Lamps

DOE CALiPER Test ID	Initial Output (lm)	Total Input Power (w)	Efficacy (lm/W)	Power Factor	CRI	CCT
07-08	229	8.8	27	0.58	72	2945
07-09	310	9.1	34	0.59	82	5973
07-13	406	15.6	26	0.47	14	2689
07-14	352	13.8	25	0.46	13	4006
07-18	180	8.6	21	0.60	77	7878
09-64	186	3.5	53	0.50	71	5554
RT42	365	8.0	46	0.49	67	3225
Minimum	180	3.5	21	0.46	13	2689
Mean	291	9.6	33	0.53	57	4610
Maximum	406	15.6	53	0.60	82	7878

As we can see from the earlier results of the testing the efficacy, of the LED lamps were between 21 to 53 (lm/W) with a mean of 33 lm/W. The minimum lumen output and the minimum efficacy of these LED lamps don't come close to the conventional lamps tested by CALiPER and shown in Table 9. Although the mean efficacy of the LED and conventional are close, the mean lumen outputs do not come close.

Table 10 CALiPER Testing of Conventional BR30 and R30 Lamps

DOE CALiPER Test ID	Source Type	Initial Output (lm)	Total Input Power (w)	Efficacy (lm/W)	Power Factor	CRI	CCT
12-54	Incandescent	650	65.7	10	1.00	100	2698
08-13	Incandescent	732	65.0	11	1.00	99	2681
12-21	CFL	776	14.9	52	0.60	83	2684
12-58	CFL	732	16.1	46	0.57	83	2883
08-06	CFL	841	15.8	53	0.55	82	2740
Minimum		650	14.9	10	0.55	82	2681
Mean		746	35.5	34	0.74	89	2737
Maximum		841	65.7	53	1.00	100	2883

In the most recent CALiPER study, 13 LED lamps were tested and the results are considerably different than previous LED test data. The efficacy of these newer products are in the range of 51 to 91 (lm/W) with a mean of 59 lm/W, which is very comparable and in many cases much better than the conventional

lamps. The lumen output of these LED's is from 463 to 860 lumens with a mean of 662 lumens. The light output of these products is also well comparable to the conventional lamps. CALiPER tested for color consistency and color temperature and for other characteristics and the results are shown in the Table 10.

Table 11 Results of the CALiPER Testing of BR30/R30 for the series 16 LED Lamps

DOE CALiPER Test ID	Initial Output (lm)	Total Input Power (w)	Efficacy (lm/W)	Power Factor	CRI	CCT
12-15	544	6.0	91	0.53	81	5389
12-16	564	11.1	51	0.97	83	3520
12-17	745	12.1	62	0.74	84	2675
12-18	859	14.0	61	0.78	81	2704
12-19	740	11.3	65	0.98	77	6586
12-20	550	9.5	58	0.93	83	2769
12-51	595	11.7	51	0.88	92	2663
12-52	463	8.1	57	0.93	85	2966
12-53	616	12.1	51	0.94	93	2729
12-55	699	13.5	52	0.76	83	2734
12-56	667	11.6	58	0.87	82	2709
12-57	705	12.6	56	0.80	82	3112
12-59	860	14.3	60	0.77	81	3000
Minimum	463	6.0	51	0.53	77	2663
Mean	662	11.4	59	0.84	84	3350
Maximum	860	14.3	91	0.98	93	6586

A few of the conclusions that CALiPER reported for the LED testes were:

- The lumen output of many of the products was equivalent to 65 Watt or 75 Watt incandescent BR30/R30 lamps.
- Most of the “series 16” LED's had color quality attributes similar to incandescent lamps.
- The power factor of the “series 16” LED's was considerably better than previously tested LED BR30/R30 lamps, with all but one of the products exceeding the ENERGY STAR minimum requirements.
- Many of the manufacturer claims were accurate; however, there was a tendency for the lamps to exhibit higher efficacies than reported in the manufacturer's literature.

1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

The base case is split into 40% CFL and 60% halogen/incandescent. This workpaper complies with the 2017 “Comprehensive Workpaper Disposition for: Screw-In Lamps” Disposition from the California Public Utilities Commission; Energy Division, dated May16, 2017.

Section 2. Calculation Methods

Wattage Reduction Ratio (WRR) savings estimation methodology is used per 2017 “Comprehensive Workpaper Disposition for: Screw-In Lamps” Disposition from the California Public Utilities Commission; Energy Division, dated May 16, 2017, based on values in Table 5 to calculate the energy savings. The demand difference (Δ Watts/lamp) is simply the difference between the electric demand of the base case lamp and the electric demand of the measure case lamp. The base case wattage of the lamp is calculated by applying the WRR multiplier to the lowest measure case wattage within the measure case range.

$$\Delta \text{Watts/lamp} \left[\frac{\text{Watts}}{\text{lamp}} \right] = (\text{Measure Case Watts/lamp} \times \text{WRR}) - (\text{Measure Case Watts/lamp})$$

$$\Delta \text{Watts/lamp} \left[\frac{\text{Watts}}{\text{lamp}} \right] = (\text{Base Case Watts/lamp}) - (\text{Measure Case Watts/lamp})$$

2.1 Electric Energy Savings Estimation Methodologies

The energy savings calculation uses the wattage reduction ratio (WRR) methodology. 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:

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

$$\Delta \text{kW/lamp} = \frac{(\text{Measure Case Wattage} \times \text{WRR}) - \text{Measure Case Wattage}}{1000}$$

Where

The following example calculation demonstrates the annual energy savings, kWh per year, for the ASM building type, for a 6W LED R/BR lamp:

Example:

$$\text{Annual Energy Savings} \left[\frac{\text{kWh}}{\text{lamp}} \right] = \frac{((6 * 5.24) - 6) \times (1160) \times (1.04)}{1000} = 30.7$$

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:

$$\text{Demand Savings} \left[\frac{\text{kW}}{\text{lamp}} \right] = (\Delta \text{kW / lamp}) \times (\text{lighting Coincident Demand}) \times (\text{Demand Interactive Effects})$$

The following example calculation demonstrates the annual energy demand savings, kW per year, for the ASM building type, for a 6W LED R/BR lamp:

$$\text{Demand Savings} \left[\frac{\text{kW}}{\text{lamp}} \right] = ((0.006 * 5.24) - 0.006) \times (0.221) \times (1.18) = 0.0066$$

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:

$$\text{Annual Gas Savings} \left[\frac{\text{Therm}}{\text{lamp}} \right] = \left(\Delta \frac{\text{kWatts}}{\text{lamp}} \right) \times (\text{AnnualHoursOfUse}) \times (\text{GasInteractive Effects})$$

The following example calculation demonstrates the annual energy demand savings, kW per year, for the ASM building type, for a 6W LED R/BR lamp:

$$\text{Annual Gas Savings} \left[\frac{\text{Therm}}{\text{lamp}} \right] = ((0.006 * 5.24) - .006) \times (1160\text{hrs} / \text{yr}) \times (-0.0099) = -0.292$$

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 and commercial 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 and commercial market sector and the lighting end-use.

Table 12 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. To comply with the May 26th, 2017 disposition we used the same cost information but changed the percentages in the base cost as per the disposition. Please refer to the LED lamp cost workbook for detailed information.

4.1 Base Case(s) Costs

The base case costs are split into 40% CFL and 60% halogen/incandescent based on 2017 “Comprehensive Workpaper Disposition for: Screw-In Lamps” Disposition from the California Public Utilities Commission; Energy Division, dated May 26th, 2017.

CFL costs are taken from the READI Tool v 2.3.0. Costs not available from READI have been interpolated. Halogen/incandescent costs are calculated from WO017⁷ workbook. The base case wattages are mapped to individual LED wattages using a table from the Energy Star Calculator.

4.2 Measure Case Costs

An average equation was calculated using the equations for reflector lamps (PAR20, PAR30, PAR38, and MR16) web scraped internally from Home Depot. This average equation was used to determine the BR/R cost.

4.3 Incremental & Full Measure Costs

Table 13 Full and Incremental Measure Cost Equations

Installation Type	Incremental Measure Cost	Full Measure Cost	
		1 st Baseline	2 nd Baseline
ROB NEW/NC	(MEC + MLC) – (BEC + BLC)	(MEC + MLC) – (BEC + BLC)	N/A
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 \$4.48 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 CALiPER, Application Summary Report 16: LED BR30 and R30 Lamps, July 2012

⁵ The Support table “Measure Application Type” in the Measure Catalog can be found using the latest version of the Remote Ex-Ante Database Interface (READI) on the Database for Energy-Efficient Resources (DEER) website,
<http://www.deeresources.com/>

⁶ Non-DEER Work Papers and Dispositions (2013 – 2017), Screw In Lamps Disposition,
<http://www.deeresources.com/index.php/non-deer-workpapers>

⁷ 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014.