**Work Paper PGECOLTG141**

**LED PAR Lamps**

**Revision 6**

**Pacific Gas & Electric Company**

**LED PAR16, PAR20, PAR30 and PAR38 Lamps**

**Measure Codes LD03, LD167-LD195, LT064-LT066**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LD03, LD167-LD195 LED, LT064-LT066 PAR Lamps |
| **Measure Description:** | LED PAR lamps replacing halogen PAR lamps. |
| **Energy Impact Common Units:** | Lamp. |
| **Base Case Description:** | Halogen PAR lamp  Source: Energy Star, DOE and PG&E Calculations. |
| **Base Case Energy Consumption:** | Various. Refer to .xlsx file attached  Source: DEER 2016(wattage reduction ratio of PAR16=4.70, PAR20=4.70, PAR30=3.42, PAR38=3.81) |
| **Measure Energy Consumption:** | Various. Refer to .xlsx file attached  Source: Energy Star and Lighting Facts |
| **Energy Savings (Base Case – Measure)** | Various. Refer to .xlsx file attached  Source: DEER 2016 |
| **Costs Common Units:** | $ per lamp. |
| **Base Case Equipment Cost ($/unit):** | Various.  Refer to .xlsx file attached |
| **Measure Equipment Cost ($/unit):** | Various.  Refer to .xlsx file attached |
| **Measure Incremental Cost ($/unit):** | Various.  Refer to .xlsx file attached |
| **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-MLtgLED-Deemed | NonRes | 0.6 | | Com-Default>2yrs | Com | 0.6 | | Res-sAll-MLtgLED-Deemed | Res | 0.6 | | Res-Default>2 | Res | 0.55 |   Source: DEER 2016 |
| **Important Comments:** | PAR16 measure codes are added with the same WRR as PAR20. IOU’s further evaluation of the whole WRR methodology and the suggestions would apply to the whole workpaper in the future when the new methodology gets accepted by ED.  “OTR”-This code stands for “Other” building type and it is only used when the customer doesn’t select a building type in the application or the building type doesn’t fall under any of the DEER approved building types. “OTR” building type savings are calculated using the "minimum kwh savings row" of valid DEER building types. If all kwh are zero, use minimum kw row. If all kwh and kw are zero, use minimum therm. For a lighting measure with all building types, the “MTL” building type will be equivalent to OTR because it is the lowest hours of operation. |

# Document Revision History

**Revision # Date Description Author (Company)**

|  |  |  |  |
| --- | --- | --- | --- |
| Revision 0 | 07/21/11 | PGECOLTG141R0-LED PAR Lamps | Alina Zohrabian (PG&E) |
| Revision 1 | 06/17/12 | PGECOLTG141R1-LED PAR Lamps  Note: updated for 2013-2014 | Alina Zohrabian (PG&E) |
| Revision 1 | 8/29/12 | 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 2 | 7/13/13 | Revised Savings values per ED Workpaper Disposition for Lighting Retrofit, issue March, 2013. For updated savings values, see file PGECOLTG109 R4-Calcs.xlsx  For measure L037 PG&E used 7 watts for the measure wattage this went down to 5.5 watts. For measure L038 PG&E used 11 watts for the measure wattage this went down to 8 watts. For measure L039 PG&E used 15 watts for the measure wattage this went down to 14 watts. For measure L045 PG&E used 17 watts for the measure wattage this went down to 16 watts. For measure L040 PG&E used 13 watts for the measure wattage this went down to 8 watts. For measure L041 PG&E used 18 watts for the measure wattage this went down to 16 watts. For measure L044 PG&E used 21 watts for the measure wattage this went down to 20.1 watts. | Alina Zohrabian (PG&E) |
| Revision 3 | 10/09/13 | Measure wattages are broken down into more refined wattage ranges. Please refer to PGECOLTG141 R3-Calcs.xlsx for savings values. | Alina Zohrabian (PG&E) |
| Revision 4 | 3/21/14 | Added DI values from (PGE3PLTG178) and Revised savings values per ED Workpaper Disposition for lighting Retrofit, December 14, 2013. For updated savings values, see file PGECOLTG141 R4.xlsx | Alina Zohrabian (PG&E) |
| Revision 5 | 1/1/2016 | Updated NTG, EUL, CDF, IE, hours of operation per DEER 2016. Costs have also been updated. | Linda Wan (PG&E)/ Alina Zohrabian (PG&E) |
| Revision 6 | 6/10/2016 | PAR16 measure codes are added with the same WRR as PAR20. IOU’s further evaluation of the whole WRR methodology and the suggestions would apply to the whole workpaper in the future when the new methodology gets accepted by ED. Cost for PAR16 is done by web search. | Alina Zohrabian (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper details the replacement of existing halogen Parabolic Aluminized Reflector (PAR) PAR16, PAR20, PAR30 and PAR38 lamps with LED PAR20, PAR30 and PAR38 lamps.

**Requirements:**

* Must replace a halogen PAR lamp
* Must be on the Energy Star qualified product list and be listed with the Department of Energy Lighting Facts Program.

Table 1 Measure Codes and Description

|  |  |
| --- | --- |
| **Product Code** | **Description** |
| LT064 | LED PAR16: <6 Watts |
| LT065 | LED PAR16: 6 to < 7 Watts |
| LT066 | LED PAR16: ≥7 Watts |
| LD03 | LED PAR20: ≤11 Watts |
| LD167 | LED PAR30: <10 Watts |
| LD168 | LED PAR30: 10 to <11 Watts |
| LD169 | LED PAR30: 11 to <12 Watts |
| LD170 | LED PAR30: 12 to <13 Watts |
| LD171 | LED PAR30: 13 to <14 Watts |
| LD172 | LED PAR30: 14 to <15 Watts |
| LD173 | LED PAR30: 15 to <16 Watts |
| LD174 | LED PAR30: 16 to <17 Watts |
| LD175 | LED PAR30: 17 to <18 Watts |
| LD176 | LED PAR30: 18 to <19 Watts |
| LD177 | LED PAR30: 19 to <20 Watts |
| LD178 | LED PAR30: ≥20 Watts |
| LD179 | LED PAR38: < 12 Watts |
| LD180 | LED PAR38: 12 to <13 Watts |
| LD181 | LED PAR38: 13 to <14 Watts |
| LD182 | LED PAR38: 14 to <15 Watts |
| LD183 | LED PAR38: 15 to <16 Watts |
| LD184 | LED PAR38: 16 to <17 Watts |
| LD185 | LED PAR38: 17 to <18 Watts |
| LD186 | LED PAR38: 18 to <19 Watts |
| LD187 | LED PAR38: 19 to <20 Watts |
| LD188 | LED PAR38: 20 to <21 Watts |
| LD189 | LED PAR38: 21 to <22 Watts |
| LD190 | LED PAR38: 22 to <23 Watts |
| LD191 | LED PAR38: 23 to <24 Watts |
| LD192 | LED PAR38: 24 to <25 Watts |
| LD193 | LED PAR38: 25 to <26 Watts |
| LD194 | LED PAR38: 26 to <27 Watts |
| LD195 | LED PAR38: ≥27 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 CEC Voluntary California Quality LED Lamp Specification

|  |  |
| --- | --- |
| Upstream | Midstream / Downstream |
| Close to or meets full CEC Spec by having at least:   * CA beam shape requirements * CCT of 2700K or 3000K * CRI>=90 * R9>0 (“best in lamp class and channel”)\* * Dimmable * Must either be on THE ENERGY STAR Qualified Products List (QPL), or have begun ENERGY STAR Rated Life testing, and continue in testing until the product is accepted for the QPL. * Must be listed on the QPL within 9 months of the applicable IOU's allocation begin/confirmation date. * Must be listed on the Department of Energy LED Lighting Facts Product List within 9 months of the applicable IOU's allocation begin/confirmation date. | * Must be on THE ENERGY STAR Qualified Products List. |
| Meets ENERGY STAR Plus lamp specifications, plus at least:   * CA beam shape requirements * CCT of 2700K or 3000K * CRI>=80 (“best in lamp class and channel”) * R9>0 (“best in lamp class and channel”) * Dimmable * Must either be on THE ENERGY STAR Qualified Products List (QPL), or have begun ENERGY STAR Rated Life testing, and continue in testing until the product is accepted for the QPL. * Must be listed on the QPL within 9 months of the applicable IOU's allocation begin/confirmation date. * Must be listed on the Department of Energy LED Lighting Facts Product List within 9 months of the applicable IOU's allocation begin/confirmation date. |  |

\*Best in lamp class and channel - Utility managers will choose the products that are “best in class”. What represents “best in class” will change depending on the specific product and channel. Thus, categories with a greater number of high-CRI products available (i.e. PARs and retrofit kits) will be held to a higher standard than other categories with fewer options (i.e. A-Lamps and BRs). Furthermore, channels with more choices of energy efficient lighting (i.e. large home improvement stores) will be held to a higher standard than other categories with fewer options (i.e. mom and pop hardware stores).

***Terms and Conditions***

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

***Market Applicability***

PAR lamps are primarily used in the retail market and grocery stores for display lighting; however, this measure applies to all commercial buildings and to the residential market as well.

Please refer to the table below for delivery method and applicable building types:

Table 3 Delivery Method and Applicable Building Types

|  |  |
| --- | --- |
| **Delivery Type** | **Applicable Building Types** |
| Upstream/Midstream | “Com” & “Res” |
| Downstream | DEER Building Types |
| Direct Install | DEER Building Types |

## 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.

Comparing the results of the CALiPER test summaries[[1]](#endnote-1), starting in Round 3 where they included the testing of the LED Parabolic Aluminized Reflector (PAR) lamps, with the results of the later CALiPER tests, the LED PAR lamps improved not only in their lumen output and efficacy but also in their correlated color temperature, color rendering index, power factor, heat control and lamp beam directivity. These improvements are seen in many of the LED lighting products and make this technology promising for the near future in most lighting applications.

## 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 4 Measure Application Type[[2]](#endnote-2)

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 base case wattages of the halogen PAR lamps are calculated based on the Energy Division wattage reduction ratios (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 PAR lamps using the WRR method. The base case is calculated using the WRR in the following table:

Table 5 Wattage Reduction Ratios

|  |  |
| --- | --- |
| **Lamp** | **WRR** |
| PAR16 | 4.70 |
| PAR20 | 4.70 |
| PAR30 | 3.42 |
| PAR38 | 3.81 |

**Hours of Operation**

The DEER 2016 hours of operation and interactive effects are used for the 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** | **Measure Delivery** | **NTGR** |
| NonRes-sAll-MLtgLED-Deemed | Nonresidential LED: replacing CFL or incandescent lamps; deemed; all delivery mechanisms except upstream | Any | Any | NonUpStrm | 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-sAll-MLtgLED-Deemed | Residential LED: replacing CFL or incandescent lamps; deemed; all delivery mechanisms except upstream | Res | Any | NonUpStrm | 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 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** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |
| Com-LED-PGE | Non-Res LED; Non-Upstream Program; Annual Installation Rate | Com | Any | NonUpStrm | 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 20,000 hours. 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:



Table 8 Effective Useful Life/Remaining Useful Life

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

## 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 many demonstration projects and reports such as DOE Solid-State Lighting CALiPER Program’s Summary of Results1 that could be addressed. However this workpaper is using the disposition for integral LED lamp replacement guidelines from Energy Division (ED) to calculate the savings. As the LED’s 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 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

The energy savings calculation uses the wattage reduction ratio methodology.

The energy savings is calculated based on the following formula:



Sample calculation for LD03 PAR 20 for Assembly building type:



## 2.2. Demand Reduction Estimation Methodologies

The lighting demand difference (Watts per unit) is simply the difference between the electric demand of the base unit and the electric demand of the energy efficient unit. The Demand savings is calculated based on the formula below:



Sample calculation for LD03 PAR 20 for Assembly building type:



## 2.3. Gas Energy Savings Estimation Methodologies

There is no gas energy savings associated with this measure. However the negative impacts are calculated based on the formula below.



Sample calculation for LD03 PAR 20 for Assembly building type:



# 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.

These measures will use the Residential lighting and Commercial indoor lighting load shapes based on the E3 calculator and the applicable residentialand commercialmarket sector.

Table 9 Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| All Commercial Building Types | PGE:DEER:Com:Indoor\_CFL\_Ltg | NON\_RES |
| All Residential Building Types | 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.

The cost for PAR16 is done by web search, since the previously used study for this workpaper doesn’t have specific cost for PAR16.

## 4.1 Base Case(s) Costs

The base case costs are split into 25% CFL and 75% halogen/incandescent. 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 WO017[[3]](#endnote-3) workbook. The base case wattages are mapped to individual LED wattages using a table from the Energy Star Calculator.

## 4.2 Measure 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[[4]](#endnote-4) recommends using 25 percentile utilizing CA specific data.

## 4.3 Incremental & Full Measure Costs

Table 10 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 $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. DOE CALiPER *Summary Reports:* <http://www1.eere.energy.gov/buildings/ssl/reports.html> [↑](#endnote-ref-1)
2. 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.* [↑](#endnote-ref-2)
3. 2010-2012 WO017 (work-Order-17) Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014. [↑](#endnote-ref-3)
4. California LED Workpaper Update Study. Navigant Consulting. August 28, 2015. [↑](#endnote-ref-4)