**Work Paper PGECOLTG151**

**LED Outdoor Street and Area Lighting**

**Revision 5**

**Pacific Gas & Electric Company**

**Customer Energy Solutions Department**

**LED Outdoor Street and Area Lighting**

**Measure Codes: LT007 -LT024**

# At-A-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LT007-LT024 |
| **Measure Description:** | Replacement of exterior HID fixtures with LED luminaires in street and outdoor area applications. |
| **Energy Impact Common Units:** | Per fixture. |
| **Base Case Description:** | Pole-mounted HID street and area light fixtures as well as wall-mounted HID area light fixtures.  Source: PG&E Calculations |
| **Base Case Energy Consumption:** | Base case is assumed to be a metal halide fixture.  Source: PG&E Calculations |
| **Measure Energy Consumption:** | Source: PG&E Calculations |
| **Energy Savings (Base Case – Measure)** | Source: PG&E Calculations. |
| **Costs Common Units:** | $ per fixture. |
| **Base Case Equipment Cost ($/unit):** | Varies  Source: PG&E Calculations. |
| **Measure Equipment Cost ($/unit):** | Varies  Source: PG&E Calculations. |
| **Measure Incremental Cost ($/unit):** | Varies  Source: PG&E Calculations. |
| **Effective Useful Life (years):** | 12 years, OLtg-Com-LED-50000hr  Source: DEER2016 |
| **Program Type:** | Replace on Burnout or New Construction |
| **Net-to-Gross Ratios:** | NTG = 0.6, Com-Default>2yrs  Source: DEER 2016 |
| **Important Comments:** |  |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Description** | **Author (Company)** |
| Revision 0 | 11/19/08 | Original work paper | Marc Theobald (EES)  Jack Howells (EES) |
| Revision 1 | 03/20/09 | PGECOLTG151 R1 | Jim Wyatt (PG&E) |
| Revision 2 | 01/15/2010 | PGECOLTG151 R2 | Jim Wyatt (PG&E) |
| Revision 3 | 06/15/2012 | PGECOLTG151 R3 | John Rossi (EES)  Jay Martin (EES)  Jim Wyatt (PG&E) |
| Revision 3 | 8/29/12 | For Building type changed COM to ANY, For Vintage AV is changed to ANY and For Climate Zone All is changed to ANY (Since this measure is for Exterior Lighting) | Alina Zohrabian (PG&E) |
| Revision 4 | 05/22/2014 | Added DI values and applied the 2014 IE and Hours from DEER (posted 2/20/14). For updated savings values, see file PGECOLTG151 R4.xlsx. | Tai Voong (PG&E) |
| Revision 5 | 1/1/2016 | Added NC for measure application type. Updated NTG values & EUL ID per DEER 2016. Updated base case costs and measure costs. | Linda Wan (PG&E)/ Alina Zohrabian (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

***Catalog Description –***

Light emitting diode (LED) technology has proven to be an effective lighting source that can offer substantial savings over typical high intensity discharge (HID) lighting technologies. The light is easily controllable and can be turned on and off instantly or dimmed for added energy savings at dawn and dusk. LED streetlights are available from a variety of vendors and offer many advantages over traditional streetlight technologies. Some of the other advantages include:

* No mercury or other hazardous chemical and gasses in the LEDs
* Long lifetimes and highly reliable service, greatly reducing maintenance costs
* White light available in color temperatures from “warm” to “cool” with high CRI providing high-quality white light.

Table 1 Measure Codes and Descriptions

|  |  |
| --- | --- |
| **Measure Code** | **Measure Description** |
| LT007 | LED Outdoor Area Lighting - Install 501-750 W Fixture |
| LT008 | LED Outdoor Area Lighting - Install 266-500 W Fixture |
| LT009 | LED Outdoor Area Lighting - Install 226-265 W Fixture |
| LT010 | LED Outdoor Area Lighting - Install 193-225 W Fixture |
| LT011 | LED Outdoor Area Lighting - Install 151-192 W Fixture |
| LT012 | LED Outdoor Area Lighting - Install 111-150 W Fixture |
| LT013 | LED Outdoor Area Lighting - Install 71-110 W Fixture |
| LT014 | LED Outdoor Area Lighting - Install 51-70 W Fixture |
| LT015 | LED Outdoor Area Lighting - Install 0-50 W Fixture |
| LT016 | LED Street Lighting - Install 501-750 W Fixture |
| LT017 | LED Street Lighting - Install 266-500 W Fixture |
| LT018 | LED Street Lighting - Install 226-265 W Fixture |
| LT019 | LED Street Lighting - Install 193-225 W Fixture |
| LT020 | LED Street Lighting - Install 151-192 W Fixture |
| LT021 | LED Street Lighting - Install 111-150 W Fixture |
| LT022 | LED Street Lighting - Install 71-110 W Fixture |
| LT023 | LED Street Lighting - Install 51-70 W Fixture |
| LT024 | LED Street Lighting - Install 0-50 W Fixture |

***Program Restrictions and Guidelines***

To qualify for a rebate, the following requirements must be met:

* The LEDs must replace high intensity discharge, low pressure sodium, or incandescent lighting.
* Proposed fixture must be Design Lights Consortium (DLC) listed.[[1]](#endnote-2)
* The pole/arm-mounted area and roadway luminaires must meet a minimum efficacy of 60 lumens per watt.[[2]](#endnote-3)
* Luminaire/enclosure type must be certified by NEMA/IEC as wet location for exterior parking, roadway, area, or wall-mounted luminaires and damp (or wet) location for parking garage luminaires.
* Power supply shall have a minimum operating temperature of –20°C or below when used in luminaires intended for outdoor applications.
* Not to exceed the power supply manufacturer’s maximum recommended case temperature or TMP when measured during in-situ operation. **Note:** This performance characteristic is separate and distinct from thermal requirements established by UL, which governs safety rather than longevity of the power supply.
* Luminaires must possess a power factor greater than 0.9.
* The LEDs must possess less than 20% of total harmonic distortion.
* A written warranty must be issued to the customer guaranteeing repair or replacement of defective electrical parts (including light source and power supplies) for a minimum of five years from the date of purchase.
* A product cut sheet and installation instructions must be provided.

***Terms and Conditions***

The customer must be a PG&E electrical customer served under a streetlight or commercial/industrial rate schedule.

***Market Applicability***

This measure applies to the Customer-Owned Street and Highway Lighting, Outdoor Area Lighting Service, and the commercial/industrial rate schedules. This program has both Downstream and Direct Install components.

***1.2 Product Technical Description***

Light emitting diode (LED) technology has improved in the past decade, enabling efficacious LED light sources with comparable lumen output to some existing baseline lighting sources. Current technology is beginning to allow for the level of lumen output traditionally associated with outdoor lighting application, given similar levels of power consumption. As LED component technology, such as optics and drivers, continues to improve, LED light sources become increasingly competitive with the lumen output emitted by high intensity discharge (HID) outdoor lighting, of which high and low pressure sodium (HPS and LPS) and metal halide (MH) are the most commonly employed forms.[[3]](#endnote-4)

Solid-state lighting sources offer other benefits as well. Manufacturer’s claims cite a more focused light output, with less light lost to the peripheries. Case studies[[4]](#endnote-5), [[5]](#endnote-6) indicate that LED light sources offer more even distribution of lighting, providing less variance in maximum to minimum ratios. Longer life and low to nil maintenance costs are also great advantages of LED technology. Additionally, LED light sources have the ability to dim where other, more typical baseline fixtures cannot. These advantages continue to increase the size of the solid-state lighting foothold in exterior lighting applications.

Further benefits of LED light sources include compact size, durability and shock-resistance, no infrared (IR) or ultraviolet (UV) emissions, wide color temperature range, monochromatic light, no burn out, near instant-on and rapid cycling, good performance in the cold, no toxic metals or chemicals, and LEED ND point contribution.[[6]](#endnote-7)

The spectrum and quality of light output by LED sources is such that, some propose, it is a more effective form of nighttime lighting. Theories concerning color temperature and visual effect continue to be debated; therefore, this topic lies outside the scope of this work paper. Nonetheless, this work paper considers light distribution and uniformity as key elements in proposed replacement strategies for street and area lighting applications (pole-mounted luminaires with full cutoff).[[7]](#endnote-8)

The primary goal of these measures is to replace the energy intensive HID technology that is typically employed. Retrofits are defined as the replacement of the entire lighting fixture, but not necessarily system, as street poles or other structural elements will often remain in place. Simple lamp replacements are not applicable to these measures because outdoor LED lighting systems are currently sold as entire luminaires or retrofit kits.

## 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 2 Measure Application Type[[8]](#endnote-9)

*Identifies the measure application type in the Measure Implementation table in DEER2011.*

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
|  |  |  |
| 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* |
|  |  |  |

These measures are identified as ROB and NC.

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

The DEER READI tool was used to identify DEER base case and measure case. Please refer to the Excel calculation workbook for DEER measure IDs.

**Hours of Operation**: Hours of operation are assumed to be 4,100 hours per year for those measures for which nighttime operation alone is expected. This estimate was verified against PG&E’s *Electric Schedule LS-2* as a source of current operation practices.14

**Net-to-Gross Assumption:** The NTG values were obtained using the NTG workbook provided on the DEER 2016 website[[9]](#endnote-10). The relevant NTG values for the measures in this work paper are listed below:

Table 3 DEER Net-to-Gross Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Delivery Method** | **NTGR** |
| 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 |

**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 4 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective Useful Life:**  The EUL value was obtained using the DEER READI tool. The relevant EUL value for the measurers in this work paper is listed in the table below:

Table 5 Effective Useful Life

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** |
| OLtg-Com-LED-50000hr | LED Fixture - Outdoor- Commercial | Com | Lighting | 12 |

## 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:*** Section 110.9 and 130.2 of Title 24 [2013] details the mandatory requirements for lighting control devices and systems, ballasts, and luminaires and outdoor lighting controls and equipment.

***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 and rated life, this work paper draws from the Commercially Available LED Product Evaluation and Reporting (CALiPER) Program of the U.S. Department of Energy. CALiPER results were used to define accurate power draw and lumen output estimates for LED technology. CALiPER results include outdoor applications in most rounds of testing, but the premise of this paper relies most heavily on Round 11, which covered outdoor applications extensively.***[[10]](#endnote-11)***

The Emerging Technologies (ET) Program Application Assessment report LED Street Lighting: Oakland, CA (Application Assessment #0714) provided the original basis for this work paper.[[11]](#endnote-12)4 Phase II of the study compared performance between nominal 100 watt high pressure sodium (HPS) and 78 watt LED street lighting. Actual wattage of the HPS luminaires was measured at 121 watts, documenting a reduction 36% in power demand. Phase III returned to the original scenario with more recent offerings from the same LED manufacturer and demonstrated increased power savings while maintaining light levels; this study replaced the same nominal 100 HPS lamps with improved 58 watt LED luminaires.

Using photopic measurements, which are conservative for a transition to high CRI, blue-spectrum sources, the minimum illuminance level was maintained at typical 110 or 120 foot spacing. While the average and maximum illuminance levels were higher with HPS lighting, it is reasonable to assume that minimum illuminance is the critical point of comparison for roadway and other outdoor applications. Furthermore, Average to Minimum Uniformity and Maximum to Minimum Uniformity ratios were less pronounced with the solid-state lighting as compared to the base case, demonstrating improved uniformity in distribution. The study also documented comparable or improved lumen maintenance over the LED system life and end user surveys, which conveyed a preference for the replacement system.

This work paper, while considering initial lumen output in replacement strategies, also accounts for this increased uniformity in light distribution. An acceptable drop in initial lumen output is an inherent assumption for the retrofits anticipated herein; this study uses the Emerging Technology report as a basis for the achievable reduction in demand while maintaining minimum illuminance levels. It should be noted that a discussion of photopic, scotopic, and mesopic illuminance remains strictly outside of the bounds of this work paper, although this topic is gaining importance in the application of solid-state lighting to outdoor end use.

In 2009 the market penetration of LED light sources was 0.01% of roadway lighting, 4.30% of parking lighting, 0.70% of area and flood lighting, and 0.00% of residential outdoor lighting.[[12]](#endnote-13) Since there is an economic incentive to reduce the frequency of maintenance and replacement of outdoor lighting, LED light sources have “further market potential as their long life continues to increase, bringing down annual costs to approximately half of HPS annual costs by 2030.”[[13]](#endnote-14)

**Delta wattage Assumption (ΔW):** This measure is based on the replacement of HID lighting sources with LED luminaires. In order to account for the breadth of application, this work paper draws on a combination of current specifications for LED technology, the existing PG&E *Electric Schedule LS-2: Customer-Owned Street and Highway,*[[14]](#endnote-15) results from the *LED Street Lighting: Oakland, CA* report,11 and CALiPER reports.10

The data from the Oakland ET report was compared to further data from the manufacturer whose products were installed in the study (whose products are independently tested following IESNA LM-79 photometric testing protocols) and compared to data from the CALiPER testing program (also based on LM-79 testing for complete luminaires at 25°C ambient temperatures).[[15]](#endnote-16) Figure 1 shows the resulting trends, which reveal coherence between the sets of data.

Figure 1 Initial Lumen Output vs. Power: Manufacturer Specifications and CALiPER



Replacement strategies were based upon a comparative reduction in power and lumen output as demonstrated in both rounds of the Oakland ET study. Phases II and III of the study show that a reduction in power draw of between 36% and 52% between baseline and LED luminaires resulted in an acceptable reduction in lumen output, both in terms of minimum illuminance levels and overall customer acceptance. Furthermore, reduction in initial lumen output was modeled in each scenario, based on initial lumen output figures for LED luminaires, reduced by 20% to reflect mean lumen output based on DOE research into lumen maintenance with LEDs, and mean lumen output figures from manufacturer lamp specifications comparable to the baseline (taken for street lighting at the horizontal burn). Baseline lamp lumen output was adjusted in the modeled scenarios by applying a luminaire efficiency coefficient from photometric files from the fixture used in the Oakland ET study. For the simulated replacement of other baseline figures, photometric files from standard cobra head and area light fixtures were used to generate luminaire efficiency coefficients. Lastly, the reduction in input wattage (calculated as 36% and 52% for Phase II and III, respectively) was modified for each wattage category to reflect the increasing efficacy of HID lamps at higher wattages. Detailed information on all assumptions is included in the accompanying calculations for this work paper.

Since the conclusion of the Oakland ET study, LED technology has improved in such a way that solid-state lighting retrofits can now offer similar power reductions, approximately 40%, with only a minor reduction in lumen output. In CALiPER Round 11, “five of the luminaires have fairly similar light output levels from 4000–5000 lumens.”10 Those outdoor roadway luminaires had an average power draw of approximately 70 W and were benchmarked against a 100 W HPS fixture and two induction roadway fixtures. Of the benchmark fixtures, the HPS drew 117 W and the two induction fixtures drew 67 W and 71 W. The benchmark fixture outputs ranged from 3,500 to 6,500 for the HPS fixture. Based on the results of CALiPER Round 11, an LED luminaire can produce comparable lumen output with a considerable 40% reduction in power. The wattage ranges in this paper are based on an approximate 40% reduction in power.

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

This work paper follows DEER 2016 updates as well as the DEER 1314 Lighting Dispositions.

# Section 2. Calculation Methods

## 2.1 Electric Energy Savings 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.

*∆watts/unit = Base watts/unit – Energy Efficient unit watts*

*Annual Electric Savings:*



The following example calculates the annual electric energy kWh savings for the “LED Street/Outdoor Area Lighting - Install 0-50 W Fixture” measure:



For the savings of all other measures, see the calculation spreadsheet that accompanies this report.

## 2.2. Demand Reduction Estimation Methodologies

There is no anticipated demand reduction associated with these measures, because the majority of the load is confined to nighttime hours.

## 2.3. Gas Energy Savings Estimation Methodologies

There are no gas energy savings associated with these measures.

# 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 non-residential outdoor 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 non-residential market sector and the outdoor lighting end-use, since load shape will not alter with new technology.

Table 6 Building Type and Load Shape

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Any | PGE:2 = Commercial Outdoor Lighting | COMMERCIAL |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case(s) Costs

RS Means electrical cost data was consulted as a reference point for current base case costs for the applications defined in this work paper.[[16]](#endnote-17)

For pricing on all measures, see the calculation spreadsheet that accompanies this report.

## 4.2 Measure Costs

RS Means electrical cost data were consulted as reference points for current measure case costs for the applications defined in this work paper.16

The labor cost used is $187.14 per WO017 for lift accessible fixtures[[17]](#endnote-18). For pricing on all measures, see the calculation spreadsheet that accompanies this report.

## 4.3 Incremental & Full Measure Costs

Table 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

For the complete list of incremental and full measure costs, see the calculation spreadsheet that accompanies this report.

# References

1. DesignLights Consortium. *Qualified Products List.* NEEPDLCQPL.xls http://www.designlights.org/solidstate.about.QualifiedProductsList\_Publicv2.php [↑](#endnote-ref-2)
2. DesignLights Consortium. *Technical Requirements Table v1.6.* http://www.designlights.org/solidstate.manufacturer.requirements.php

   *Note.* The IES holds a contrary view: “There should be no minimum performance limits set on light sources and luminaires, but correct measures in design and control should be utilized instead. The use of a lumen per watt rating for luminaires is not endorsed by the IES and does not necessarily achieve the goals of energy reduction while maintaining a high quality lighted environment. The use of an energy standard to control lighting system efficiency is far more effective and will allow a designer to implement the requirements of the design without limitations on technology.” Illuminating Engineering Society. *Standards for Energy Efficient Outdoor Lighting.* PS-4-10. 2010. http://www.ies.org/PDF/PositionStatements/PS-04-10.pdf [↑](#endnote-ref-3)
3. DOE Solid-State Lighting CALiPER Program. *Application Summary Report 15* (May 2012)—LED floodlights. http://www1.eere.energy.gov/buildings/ssl/reports.html [↑](#endnote-ref-4)
4. DOE GATEWAY Demonstrations. http://www1.eere.energy.gov/buildings/ssl/gatewaydemos\_results.html

   *Demonstration Assessment of LED Roadway Lighting: New York, New York* (December 2011)

   *Demonstration Assessment of LED Ornamental Post-Top Street Lights: Sacramento, California* (December 2011)

   *Demonstration Assessment of LED Parking Lot Lighting: Leavenworth, Kansas* (May 2011)

   *Demonstration Assessment of LED Parking Lot Lighting: Manchester, New Hampshire* (June 2010)

   *Demonstration Assessment of LED Roadway Lighting: Palo Alto, California* (June 2010)

   *Demonstration Assessment of LED Street Lighting: Lija Loop, Portland, Oregon* (November 2009)

   *Demonstration Assessment of LED Roadway Lighting: I-35W Bridge, Minneapolis, Minnesota* (August 2009)

   *Demonstration Assessment of LED Parking Lot Lighting: Raley’s Supermarket, West Sacramento, California* (February 2009)

   *Demonstration Assessment of LED Street Lighting: City of San Francisco, California* (December 2008)

   *Demonstration Assessment of LED Walkway Lighting: Federal Aviation Administration (FAA) Technical Center, Atlantic City, New Jersey* (March 2008)

   *Demonstration Assessment of LED Area Lights for a Commercial Garage: Portland, Oregon.* (November 2008)

   *Demonstration Assessment of LED Street Lighting: City of Oakland, California* (Phase II, January 2008; Phase III, November 2008) [↑](#endnote-ref-5)
5. Federal Energy Management Program. *LED Provides Effective and Efficient Parking Area Lighting at the NAVFAC Engineering Service Center (Port Hueneme, California).* August 2010. http://www1.eere.energy.gov/femp/technologies/ssl\_casestudies.html [↑](#endnote-ref-6)
6. Remaking Cities Institute, Carnegie Mellon University. *LED Street Light Research Project: Pittsburgh, Pennsylvania.* September 2011. http://www.cmu.edu/rci/publications/index.html [↑](#endnote-ref-7)
7. For information on light levels and streetlight spacing, see National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute. *Streetlights for Collector Roads.* Revision 2, November 2010. http://www.lrc.rpi.edu/nlpip/publicationDetails.asp?id=927&type=1 [↑](#endnote-ref-8)
8. 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-9)
9. Net to Gross Value Update found on [www.deeresources.com](http://www.deeresources.com) under *DEER2016 DEER Team Recommended Updates* hyperlink, spreadsheet *DEER2015-2016-NTG-Update-2015-06-03.xls.* [↑](#endnote-ref-10)
10. DOE Solid-State Lighting CALiPER Program. *Round 11 Summary Report* (October 2010)—includes roadway arm-mount and post-top luminaires. http://www1.eere.energy.gov/buildings/ssl/reports.html

    Detailed reports for 36 LED light sources for outdoor applications (as of June 15, 2012) are available at http://www1.eere.energy.gov/buildings/ssl/caliper/default.aspx [↑](#endnote-ref-11)
11. DOE GATEWAY Demonstrations. *Demonstration Assessment of LED Street Lighting: City of Oakland, California* (2008). http://www1.eere.energy.gov/buildings/ssl/gatewaydemos\_results.html [↑](#endnote-ref-12)
12. 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 [↑](#endnote-ref-13)
13. 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 [↑](#endnote-ref-14)
14. Pacific Gas and Electric Company. *Electric Schedule LS-2: Customer-Owned Street and Highway Lighting.* January 25, 2012. www.pge.com/tariffs/tm2/pdf/ELEC\_SCHEDS\_LS-2.pdf [↑](#endnote-ref-15)
15. DOE Solid-State Lighting CALiPER Program. *Summary Report 3* (May 2008). http://www1.eere.energy.gov/buildings/ssl/reports.html [↑](#endnote-ref-16)
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     [↑](#endnote-ref-17)
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