**Work Paper PGECOLTG151**

**LED Outdoor Area and Street Lighting**

**Revision 8**

**Pacific Gas & Electric Company**

**Customer Energy Solutions Department**

**LED Outdoor Area and Street Lighting**

**Measure Codes: LT282-LT324**

# At-A-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | LT282 – LT324 |
| **Measure Description:** | LED luminaires in outdoor applications (DLC v4.3 Premium Classification) |
| **Energy Impact Common Units:** | Per fixture. |
| **Base Case Description:** | Streetlight Fixtures: 100% LED  Non-Streetlight Fixtures: 100% LED  Parking Garage Fixtures: 60% LED, 20% Fluorescent, 20% MH |
| **Base Case Energy Consumption:** | Refer to PG&E Calculations |
| **Measure Energy Consumption:** | Refer to PG&E Calculations |
| **Energy Savings (Base Case – Measure)** | Refer to 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  LED Fixture – Outdoor - Commercial  Source: DEER2014 |
| **Measure Application Type:** | ROBNC (ROB or NC) |
| **Net-to-Gross Ratios:** | NTG = 0.6, Com-Default>2yrs  NTG= approx. 0.91 (To be provided by CPUC as per discussion on 4/5/2018)  All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years  Source: DEER2014 |
| **Important Comments:** | Revision 8 used an interim baseline technology for 2018 per CPUC disposition, until the Statewide ISP study on outdoor lighting is completed. |

# 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) |
| Revision 6 | 7/26/2016 | New measure codes LT067-LT073 to comply with leased street lamps requiring incentives refer to Advice Letter 4661-E. Retired LT016-LT017 because there is no uptake. Updated DI costs. | Henry Liu (PG&E) |
| Revision 7 | 12/14/2016 | -Changing measure application type from ROB and NC to ROBNC. | Henry Liu (PG&E)/Mini Damodaran (PG&E)/Alina Zohrabian (PG&E) |
| Revision 8 | 1/1/2018 | Updates based on DLC version 4.2 and proposed new baseline percentage mix pending ISP study; Retiring the old measure structure (LT007 – LT015, LT18-LT024, LT067-LT073) and adding new measure codes LT282-LT324 effective 1/1/2018 that follow closely to DLC version 4.2 primary uses | Greg Barker (Energy Solutions)/Mini Damodaran (PG&E) |
| Revision 8 | 4/11/2018 | -Updated baseline technology mix per disposition “2018OutdoorLighting-1March2018” as follows:  Street light, Roadway/Area, Wall-mounted and Canopy – 100% LED  Parking Garage - 60% LED, 20% metal halide, and 20% linear fluorescent  - Measure codes LT282-LT324 effective 1/1/2018 to follow DLC version 4.3 primary uses  - Cost is a temporary placeholder that uses IMC as a percentage of the rebate amount | Greg Barker (Energy Solutions)/Mini Damodaran (PG&E)/Linda Wan (PG&E)/ James Liu (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

Previous revisions of this workpaper focused on the replacement of High-Intensity Discharge (HID) fixtures with LED technology, with measure codes covering all general outdoor lighting categories. The baseline assumed 100% HID for all categories.

In 2016 and 2017, the IOUs received dispositions on outdoor LED lighting, as well as DEER Resolutions, which directed an update to the baselines used for outdoor LED lighting workpapers. The IOUs are collaborating to conduct a Standard Practice Baseline and Workpaper Update Study on outdoor lighting. Southern California Edison (SCE) is leading this effort and the Study is expected to be completed late 2018.

PG&E submitted PGECOLTG151 Revision 8 in November 2017 as an interim solution to be used until the Standard Practice Baseline Study is completed and was issued a 2018 Outdoor Lighting Phase 1 Disposition (filename: 2018OutdoorLighting-1March2018.pdf) on March 1, 2018. This disposition directed PG&E to perform the following:

1. Revise the baseline technology mix;
2. Revise the baseline LED efficacies, perform additional cost research; and
3. Re-analyze cost data.

PG&E received additional guidance from Commission Staff (CS) on March 26, 2018 that directed PG&E to work with CS to resolve these issues and submit a revised workpaper within two weeks of that guidance.

PG&E is resubmitting PGECOLTG151 Revision 8 LED Outdoor and Street Lighting as an interim solution with savings retroactively effective 1/1/2018. Per discussions with CS, details covering this revision (R8) and the next revision (R9) (to be submitted no later than August 31, 2018) are outlined below:

Revision 8 Updates (considered as the Interim Solution):

1. Revise base case technology mix as shown Table 1
2. LED baseline efficacies will be set to Lighting Facts 25th Percentile per wattage bin
3. Incremental measure costs are based on rebate values launched on January 1, 2018. (Note: PG&E commits to maintain these rebate values for ROB measures until the next major revision that allows us to confidently update incremental measure cost data approved.)

Revision 9, PG&E will consider (but not limit to) the following:

1. Early Retirement/ Accelerated Replacement as a measure application type. With this addition, PG&E intends to offer higher rebates for qualified projects.

For Revision 10, PG&E will consider (but not limit) to the following:

1. Update the baseline technology mix from results of standard practice baseline study
2. Explore alternate measure structures such as kilolumen and lumen bins
3. Collect program data to support annual updates to costs and efficacy levels
4. Conduct cost pair matching

Table 1 Base Case Technology Percentage Mix

|  |  |  |  |
| --- | --- | --- | --- |
| **Primary Use** | **Metal Halide(MH)**  **Base Case** | **Linear Fluorescent Base Case** | **LED Base Case** |
| Streetlight | 0% | 0% | 100% |
| Road & Area | 0% | 0% | 100% |
| Wall-Mounted | 0% | 0% | 100% |
| Canopy | 0% | 0% | 100% |
| Garage | 20% | 20% | 60% |

The following table includes PG&E’s measure codes and measure descriptions:

Table 2 Measure Codes and Descriptions

|  |  |
| --- | --- |
| **Measure Code** | **Measure Name** |
| LT282 | LED STREET LIGHTING: INSTALL 0 - 29 W FIXTURE |
| LT283 | LED STREET LIGHTING: INSTALL 30 - 45 W FIXTURE |
| LT284 | LED STREET LIGHTING: INSTALL 46 - 68 W FIXTURE |
| LT285 | LED STREET LIGHTING: INSTALL 69 - 90 W FIXTURE |
| LT286 | LED STREET LIGHTING: INSTALL 91 - 107 W FIXTURE |
| LT287 | LED STREET LIGHTING: INSTALL 108 - 146 W FIXTURE |
| LT288 | LED STREET LIGHTING: INSTALL 147 - 235 W FIXTURE |
| LT289 | LS1 LED STREET LIGHTING: INSTALL 0 - 29 W FIXTURE |
| LT290 | LS1 LED STREET LIGHTING: INSTALL 30 - 45 W FIXTURE |
| LT291 | LS1 LED STREET LIGHTING: INSTALL 46 - 68 W FIXTURE |
| LT292 | LS1 LED STREET LIGHTING: INSTALL 69 - 90 W FIXTURE |
| LT293 | LS1 LED STREET LIGHTING: INSTALL 91 - 107 W FIXTURE |
| LT294 | LS1 LED STREET LIGHTING: INSTALL 108 - 146 W FIXTURE |
| LT295 | LS1 LED STREET LIGHTING: INSTALL 147 - 235 W FIXTURE |
| LT296 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 0 - 29 W FIXTURE |
| LT297 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 30 - 45 W FIXTURE |
| LT298 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 46 - 68 W FIXTURE |
| LT299 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 69 - 90 W FIXTURE |
| LT300 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 91 - 107 W FIXTURE |
| LT301 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 108 - 146 W FIXTURE |
| LT302 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 147 - 235 W FIXTURE |
| LT303 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 236 - 390 W FIXTURE |
| LT304 | LED OUTDOOR POLE/ARM-MOUNTED AREA LIGHTING: INSTALL 391 - 571 W FIXTURE |
| LT305 | LED OUTDOOR PARKING GARAGE LIGHTING: INSTALL 0 - 38 WATTS FIXTURE |
| LT306 | LED OUTDOOR PARKING GARAGE LIGHTING: INSTALL 39 - 56 WATTS FIXTURE |
| LT307 | LED OUTDOOR PARKING GARAGE LIGHTING: INSTALL 57 - 88 WATTS FIXTURE |
| LT308 | LED OUTDOOR PARKING GARAGE LIGHTING: INSTALL 89 - 113 WATTS FIXTURE |
| LT309 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 0 - 25 WATTS FIXTURE |
| LT310 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 26 - 39 WATTS FIXTURE |
| LT311 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 40 - 58 WATTS FIXTURE |
| LT312 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 59 - 78 WATTS FIXTURE |
| LT313 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 79 - 97 WATTS FIXTURE |
| LT314 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 98 - 126 WATTS FIXTURE |
| LT315 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 127 - 203 WATTS FIXTURE |
| LT316 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 204 - 337 WATTS FIXTURE |
| LT317 | LED OUTDOOR WALL-MOUNTED AREA LIGHTING: INSTALL 338 - 493 WATTS FIXTURE |
| LT318 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 0 - 19 WATTS FIXTURE |
| LT319 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 20 - 29 WATTS FIXTURE |
| LT320 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 30 - 46 WATTS FIXTURE |
| LT321 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 47 - 59 WATTS FIXTURE |
| LT322 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 60 - 73 WATTS FIXTURE |
| LT323 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 74 - 99 WATTS FIXTURE |
| LT324 | LED OUTDOOR FUEL PUMP CANOPY LIGHTING: INSTALL 100 - 153 WATTS FIXTURE |

***Program Restrictions and Guidelines***

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

* DLC Premium LEDs must replace lumen equivalent/fixture of higher wattage, and proposed fixture must be on the DesignLights Consortium (DLC) Qualified Products List (QPL) v4.3 or later, classified as Premium, and listed under the Outdoor General Application[[1]](#endnote-2) and appropriate DLC Primary uses for the measure codes as follows:

Table Measure Code and DLC v 4.3 Primary Use Alignment

|  |  |
| --- | --- |
| **Measure Code Range** | **Eligible DLC Primary Uses** |
| LT282 – LT295 (Street light) | * Outdoor Pole/Arm-Mounted Area and Roadway Luminaires * Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires * Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires |
| LT296 – LT304 (Outdoor area pole/arm-mounted) | * Outdoor Pole/Arm-Mounted Area and Roadway Luminaires * Retrofit Kits for Large Outdoor Pole/Arm-Mounted Area and Roadway Luminaires * Retrofit Kits for Outdoor Pole/Arm-Mounted Area and Roadway Luminaires |
| LT305 – LT308 (Garage) | * Parking Garage Luminaires * Retrofit Kits for Parking Garage Luminaires |
| LT309 – LT317 (Wall-mounted) | * Outdoor Full-Cutoff Wall-Mounted Area Luminaires * Outdoor Non-Cutoff and Semi-Cutoff Wall-Mounted Area Luminaires * Retrofit Kits for Outdoor Full-Cutoff Wall-Mounted Area Luminaires |
| LT318– LT324 (Canopy) | * Fuel Pump Canopy Luminaires * Retrofit Kits for Fuel Pump Canopy Luminaires |

* Luminaires must meet a minimum efficacy in lumens per watt, based on their light output:[[2]](#endnote-3)

Table DLC v 4.3 Premium Efficacy Requirements

|  |  |  |
| --- | --- | --- |
| **General Application** | **Light Output Range (lm)** | **Minimum Efficacy (lm/W)** |
| Outdoor – Low Output | 250 – 5,000 | 110 |
| Outdoor – Mid Output | 5,000 – 10,000 | 115 |
| Outdoor – High Output | 10,000 – 30,000 | 120 |
| Outdoor – Very High Output | ≥30,000 | 120 |

* A product cut sheet and installation instructions must be provided.
* Public Utilities Code Section 384.5 requires PG&E to pay to the customer any “rebate or incentive through ratepayer-funded programs intended to increase energy efficiency.” In compliance with the statute PG&E filed Advice Letter 4661-E to revise Rate Schedule LS-1 to be applicable to IOU-owned streetlights. The Advice Letter was approved with an effective date of January 1, 2016.
* Street light and Outdoor area pole/arm-mounted categories shares the same DLC primary uses (as indicated in Table 3).
* For street lighting applications, an appropriate street light measure code must be used. LS1 street light measure codes are created for utility owned street light associated with LS-1 Rate Schedule (LT289 – LT295). Other street light measure codes (LT282–LT288) are associated with non-utility-owned street lights such as city or county-owned street lights.
* LT296 to LT304 measure codes are for Pole/Arm-mounted Area luminaires applications and cannot be used for street lighting.

***Terms and Conditions***

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

***Market Applicability***

These measures apply to Customer-Owned Street and Highway Lighting, Outdoor Area Lighting Service, and the commercial/industrial rate schedules. These measures are offered via both Downstream and Direct Install delivery types.

## 1.2 Technical Description

The following is a short excerpt from the CALiPER Snapshot for Outdoor Area Lighting[[3]](#endnote-4) that gives a high-level overview:

*Outdoor area lighting is a major contributor to nationwide energy use, and the market segment has been an important player in the transition to solid-state lighting. In terms of energy efficiency, LED outdoor area luminaires now easily outclass their conventional counterparts, such as fixtures using high-pressure sodium (HPS) lamps. Some LED products offer the same amount of lumen output for one-third of the power consumed by an HPS-based luminaire. The efficiency difference may be even greater if delivered illuminance is considered. At the same time, these LED outdoor area lighting products can provide superior color rendition, which can improve visibility. As the energy efficiency of LED outdoor area lighting has improved, there has also been a shift toward products with a warmer color temperature, which is perhaps a response to concerns about potential glare, light pollution, and health effects of nighttime lighting.*

*LED outdoor area lighting has been a major component of the LED Lighting Facts® database since its inception, consistently being one of the categories with the most products. As of September 20, 2017, area/roadway products alone comprised 21% of the database, with the other two product categories featured in this report collectively comprising approximately 5%. These percentages have been fairly consistent over the past seven years*

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 (Neighborhood Development) point contribution.[[4]](#endnote-5)

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 Installation Types and Delivery Mechanisms

The Database for Energy Efficiency Resources (DEER) developed by the California Public Utilities Commission defines the measure application type as shown in the table below.

Table 5 Measure Application Type[[5]](#endnote-6)

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

The measure application type in this work paper is identified as ROBNC applications, which is also known as NR or “Normal Replacement.”

Please refer to Section 1.6.2 Inclusion of Early Retirement (ER)/Accelerated Replacement (AR) Measure Application Type on efforts to include Early Retirement (ER) in the next iteration of the workpaper.

The workpaper supports Programs with a downstream or direct install delivery channels with replace-on-burnout or new construction measure application types.

Table Delivery Method and Applicable Building Types

|  |  |  |
| --- | --- | --- |
| **Delivery Type** | **Applicable Building Types** | **Application Type** |
| Downstream & Direct Install | DEER Building Types | ROBNC |

## 1.4 Product Base Case and Measure Case Data

### 1.4.1 DEER Data

Table – DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | Yes |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | Yes |
| DEER eQUEST Prototypes | No |
| DEER Version | DEER 2016 |
| Reason for Deviation from DEER | DEER HOU does not consider dimming and/or controls required by code; DEER does contain some of these types of exterior lighting measures. |
| DEER Measure IDs Used | N/A |

**Hours of Operation**

**Exterior road and area fixtures:** The DEER hours of operation (4100 hours per year) are used for exterior road and area fixtures. The assumed hours of operation, 4100 hours per year without occupancy control, came from DISPOSITION FOR WORKPAPERS COVERING EXTERIOR LED LIGHTING FIXTURES, issued March 1, 2017.

**Parking garages:** Parking garages are assumed to be **2613.75** hours of use. This Equivalent Full-Load Hours (EFLH) is the average of the allowed low power usage per DISPOSITION FOR WORKPAPER SCE13LG123 revision 0, issued September 30, 2016 at 35% power and lower-power usage per Title 24, section 130.2(c)3 at 20% power. The calculated mid-point or average of 20% and 35% is 27.5%, which is within the range allowed for the dimmed-power state by Title24. Calculations follow DISPOSITION FOR WORKPAPERS COVERING EXTERIOR LED LIGHTING FIXTURES, issued March 1, 2017

Operating hours with controls:

**Fuel Canopy and Wall-mounted fixtures:** Fuel Canopy Fixtures, and Wall-mounted fixtures are assumed to be mounted at 24 feet and lower, and thus require motion sensor control. The assumed hours of use are 2767.5 annually. This Equivalent Full-Load Hours number was the average of the full power and lower-power usage at 35% power (the mid-point in the 10% to 60% range allowed for the dimmed-power state by Title24, section 130.2(c)3). Calculations follow DISPOSITION FOR WORKPAPERS COVERING EXTERIOR LED LIGHTING FIXTURES, issued March 1, 2017

Operating hours with controls:

**Net-to-Gross Assumption**

The NTG value was obtained using the READI tool v.2.4.7. The relevant NTG value for the measures in this work paper is listed below:

Table 8 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 |

Per discussion with Commission Staff (CS) on April 5, 2018, the NTG value is expected to increase closer to 0.91 given the high percentage of LED fixtures in the baseline. Since updated NTG values and IDs are not yet available, PG&E has been directed to use the current NTG value until CS issues a finalized update. After CS issues a final update, PG&E will resubmit workpaper with new NTG IDs.

**Spillage Rate**

Spillage rates are not tracked in workpapers; 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 v2.4.7 tool. The relevant IR value for the measures in this workpaper is in the table below:

Table Installation Rate

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

**Effective Useful Life/Remaining Useful Life**

The EUL value was obtained using the DEER READI v2.4.7 tool. The relevant EUL value for the measurers in this work paper is listed in the table below:

Table Effective Useful Life

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| OLtg-Com-LED-50000hr | LED Fixture - Outdoor- Commercial | Com | Lighting | 12 | 4 |

### 1.4.2 Codes & Standards Requirements

***Title 20***: These measures do not fall under Title 20 [2016] of the California Energy Regulations. The Metal Halide (MH) fixtures in the base case do fall under Title 20, and the wattages used for savings calculations are based on formulae from Table N-1 on page 283 and section 1605.3(n)(1)(B) on page 318.[[6]](#endnote-7)

***Title 24:*** Section 110.9 and 130.2 of Title 24 [2016] details the mandatory requirements for lighting control devices and systems, ballasts, and luminaires and outdoor lighting controls and equipment. Power consumption is prescribed through calculations at the site level. Individual fixture optical performance is restricted only in section 130.2. This section describes the number of lumens exiting the fixtures at upward angles and angles near-horizontal, which also depends on the lighting zone.

Title 24 Section 130.1(c)7B for parking garage controls:

In parking garages, parking areas and loading and unloading areas, general lighting shall be controlled by occupant sensing controls having at least one control step between 20 percent and 50 percent of design lighting power. No more than 500 watts of rated lighting power shall be controlled together as a single zone. A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in TABLE 130.1-A. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress. Interior areas of parking garages are classified as indoor lighting for compliance with Section 130.1(c)7B. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in Section 130.2.

Title 24 Section 130.2(c)3 for outdoor luminaires mounted below 24 feet:

All installed outdoor lighting, where the bottom of the luminaire is mounted 24 feet or less above the ground, shall be controlled with automatic lighting controls that meet all of the following requirements:

A. Shall be motion sensors or other lighting control systems that automatically controls lighting in accordance with Item B in response to the area being vacated of occupants; and

B. Shall be capable of automatically reducing the lighting power of each luminaire by at least 40 percent but not exceeding 90 percent, or provide continuous dimming through a range that includes 40 percent through 90 percent, and

C. Shall employ auto-ON functionality when the area becomes occupied; and

D. No more than 1,500 watts of lighting power shall be controlled together

EXCEPTION 3 to Section 130.2(c)3: Outdoor lighting, where luminaire rated wattage is determined in accordance with Section 130.0(c), and which meet one of the following conditions:

A. Pole-mounted luminaires each with a maximum rated wattage of 75 watts; or

B. Non-pole mounted luminaires with a maximum rated wattage of 30 watts each; or

C. Linear lighting with a maximum wattage of 4 watts per linear foot of luminaire.

***Federal Standards:*** Department of Energy (DOE) regulates Metal Halide outdoor lamps via a Metal Halide Light Fixture standard enforced starting February 10, 2017.[[7]](#endnote-8)

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

LED quantitative and qualitative performance information came from the following sources:

1. Technical Requirements version 4.3 of the DesignLights Consortium2 for measure case;
2. Lighting Facts Programs of the U.S. Department of Energy for base case.***[[8]](#endnote-9)***

### 1.5.1 Emerging Technologies: LED Street Lighting

The Emerging Technologies (ET) Program Application Assessment report LED Street Lighting: Oakland, CA (Application Assessment #0714) provided the original basis for this work paper.[[9]](#endnote-10)

### 1.5.2 Lighting Dispositions

The CPUC addressed exterior lighting as part of the 2018 Outdoor Lighting Phase I Disposition, and Final Resolution E‑4867 for DEER Updates, which generally re-affirmed the guidance that the CPUC had provided in previous dispositions. Highlights of the CPUC dispositions (in reverse chronological order) is included below. The Standard Practice Baseline and Workpaper Update Study currently being scoped seeks to provide supporting data in response to this direction.

* 3/1/18 (2018 Outdoor Lighting Phase 1 Disposition): “The Ex Ante Review (EAR) team review provides a strong indication from the cost analysis that the baseline, for the measure types and expected project types (not “one off” fixture replacements) covered by the workpaper, should be 100% LEDs in many cases…Revise the baseline technology mix for normal replacement and new construction (ROB / NR/ NC) and the second baseline for accelerated replacement (AR) measures as follows:

Table Base Case Technology Percentage Mix

|  |  |  |  |
| --- | --- | --- | --- |
| **Primary Use** | **Metal Halide(MH)**  **Base Case** | **Linear Fluorescent Base Case** | **LED Base Case** |
| Streetlight | **0%** | **0%** | **100%** |
| Road & Area | **0%** | **0%** | **100%** |
| Wall-Mounted | **0%** | **0%** | **100%** |
| Canopy | **0%** | **0%** | **100%** |
| Garage | **20%** | **20%** | **60%** |

In addition, the disposition directed PG&E to revise the baseline LED efficacies, perform additional cost research; and re-analyze cost data.

* 8/24/17 (Final Resolution E-4867): “Commission staff has already directed the PAs to complete a standard practice study for the purposes of investigating and confirming the standard practice for exterior LED lighting, including street lights. This direction was in response to the direction in Resolution E-4795 that the SP baseline for outdoor lighting shall be set to LED technologies as of 1/1/2018
* 6/2/17 (“Revised Disposition for workpapers covering exterior LED lighting fixtures”) states, “Commission Staff has chosen to delay direction for development of a standard practice baseline and waives any further review of the baselines.”
* 4/12/17 (“Disposition for workpapers covering exterior LED lighting fixtures – draft Clarifications of Commission Staff Baseline Direction”): This disposition directs the Program Administrators (PA) to “update the baseline for exterior lighting measures of all measure application types (ER, ROB, NR) to reflect a standard practice for exterior lighting applications”.
* 3/1/17 (Disposition for workpapers covering exterior LED lighting fixtures): “The DEER2018 update defines the standard practices for exterior lighting measures to be LED technologies. This does not mean that all LED measures should be removed from programs. Instead, PAs should perform research on LED products intended to differentiate between various performance levels of LED products, with the objective of identifying the highest performing LED products to include in their programs.”
* 2/15/17 (SCE-16-C-C-0073-0500804246\_Ext. LED Lighting (Second Review)”): “Commission believes the use of LED lighting is ISP for parking lot retrofits and likely also for other exterior and interior lighting retrofits…For exterior lighting projects, the PAs…shall…enumerate the situations where ISP is likely an LED technology and thus significantly different from current code or regulation requirements…The PAs (or SCE individually) shall proceed to immediately work collaboratively with CS to develop an ISP technology assignment appropriate for identified measures to be used in place of the code or regulation as the baseline for ROB / NR/ NC/CE and the second period baseline for ER.”
* 8/18/16 (Resolution E-4795): “DEER standard practice baseline for outdoor lighting early retirement measures has been revised to be LED technologies. The specific baseline technologies need to be developed through workpapers or custom project support documentation as new exterior lighting measures are introduced into programs. The second baseline will be applicable to all nonresidential measures covering outdoor general lighting measures. As a result of the change in standard practice baseline to LED technologies, all currently approved outdoor lighting measures (except screw-in CFLs) will no longer be approved for early retirement measures after December 31, 2017 ... PAs may submit workpapers where the measure technology meets or exceeds the current DEER code baseline (Pulse Start Metal Halide). For these measure and code baseline technologies shall be identical, resulting [in] savings for [the] RUL period only. Note that this change only affects early retirement measures and that DEER code baselines would apply to normal replacement measures.”

### 1.5.3 California LED Pricing Analysis, Navigant 2018[[10]](#endnote-11)

This market study to evaluate LED product pricing was completed by Navigant Consulting, Inc. in January 2018. This study’s objectives included 1) identifying the range of current prices for DLC and ENERGYSTAR qualified LED products in the California non-residential lighting market for certain priority product categories selected by the IOUs including LED Outdoor lighting product categories, 2) determining what factors significantly influence LED price, 3) developing an incremental cost estimate relative to identified baseline technologies (MH, HPS, LF, CFL), and to 4) determine how, and at what rate LED price ranges are anticipated to change as the market matures 3 and 5 years out from 2017.

Price data from 2016 Q4 and 2017 Q2 was collected from California IOU Program data and from Navigant Research’s LED Price Tracker, which utilizes web-scraping software to collect data on product pricing and specifications online. Of the LED products, only those that met DLC’s technical requirements were included in the study analysis. To determine which factors significantly influence LED prices, a multiple variable regression was conducted to determine the correlation between various product specifications and price.

The results of the study initially showed that the biggest driver influencing LED price is lumen output, followed by manufacturer, DLC qualification, and CRI. Efficacy was not one of the significant price determining characteristics. Furthermore, even as DLC efficacy requirements have increased over time, prices have continued to decline. According to the study, price does not appear to scale with efficacy for any of the LED product categories evaluated, including LED Outdoor Lighting. LED deemed lighting measures have assumed that measure costs have scaled with efficacy, therefore this finding that efficacy may not be a key price driver implies that further analysis should be conducted to consider how to incorporate other price drivers in measure design to encourage the adoption of higher degrees of efficiency. PG&E will consider a measure structure that is tiered by both lumen output and efficacy in future workpaper updates that may include separate efficacy tiers. Further research studies to explore and understand the barriers to market adoption other than pricing are needed for future workpaper updates.

Figure 1 below (Figure 3-5 in study) shows that the relationship between price and efficacy is highly randomized and there is a large spread in the dataset. Although the Figure shows LED troffers, this phenomenon can be seen across the other lighting categories as well.



Figure 1: Web-based LED Price and Efficacy Data for Recessed Troffer/Panel 2’ x 4’ (Source: California LED Pricing Analysis, Navigant, January 2018)

Lumen output and wattage have a direct relationship, increasing or decreasing proportionally. Therefore, the study’s indication that lumen output is a main driver of LED prices can also be interpreted that wattage may be a primary price driver. Since both factors could not be tested simultaneously due to their collinearity, only one was tested. Increasing lumen output in a product would also require increasing power load which could lead to eventually more drivers or more sophisticated drivers, which adds cost to the LED product. This supports traditional IOU Program rebate structure of offering higher incentives for higher wattage products because as wattage increases, so does product purchase price.

The study also noted that the cost to manufacture a product is separate from the consumer purchase price of that product. So, although it may cost more to increase the efficacy of a product, that additional cost is not being reflected in the purchase price the way lumen output/wattage and manufacturer affect product price. It could be that manufacturers are making trade-offs with other performance parameters to keep prices down as they improve efficacy, but that was not evaluated in this study and could be important future research to better understand the factors that influence LED price.

Another important finding of this study was that a larger portion of retrofit installations include replacing lamps and ballasts only and not entire fixtures. This is due to the extremely long life of commercial baseline (MH, HPS, induction, linear fluorescent) fixtures. This may have implications for this workpaper since it currently assumes a fixture-to-fixture comparison between base case and measure case. The incremental measure cost in the two scenarios is very different. Since a common consumer purchasing scenario includes replacement lamps and ballasts only, workpapers should consider including that scenario in the baseline. This will be investigated for a future revision of this workpaper.

The study determined that prices will continue to decrease over the next 5 years; however, the rate of decline is slowing across all product categories. It will continue to be important to closely monitor LED prices and update workpapers at least annually.

### 1.5.4 LED Workpaper Update Study, Navigant 2015[[11]](#endnote-12)

The LED Workpaper Update Study, also conducted by Navigant Consulting Inc from 2015 was similar to the study completed in 2018. Its objective was to develop findings and recommendations for updates to key parameters and methodologies used in the workpapers, program planning, and parts of the DEER database that target light-emitting diodes (LEDs), to ensure that IOU lighting programs can keep up with rapid changes in LED pricing and efficacy.

Three key research topics for high priority LED product categories were 1) LED pricing (for both residential and non-residential products), 2) Non-residential baseline wattages (which inform the selection of appropriate wattage reduction ratios or wattage ranges), and 3) the ability of the currently used savings estimation methods to predict non-residential baselines (e.g., wattage reduction ratio and wattage ranges).

Price data was collected through web-scraping, market-actor surveys of contractors, distributors, and commercial end users, and through in-depth interviews with manufacturers and retailers. The study developed price estimates that were current for 2015, and it also looked at factors that affect pricing and how often workpapers need to be updated to include most current pricing.

The 2015 study found higher annual percentage price declines for LED products which have since slowed down as shown in the 2018 study. While annual decreases for LED luminaires were found to be 20% per year from 2015-2018, they are now expected to be 9% per year from 2017-2020 decreasing to 8% per year from 2020-2022 on average across all product categories (10% annual rate of decline from 2017-2020 for LED outdoor lighting and 9% annual rate of decline from 2020-2022. However, accuracy of these price projections may be limited due to the small dataset.

The study suggested price assumptions be updated annually using web-scraping until prices stabilize. This will help ensure projections of LED price remain useful to the IOUs.

The study also found that regional price differences in California are negligible and so all IOUs can use the same cost data in workpapers.

In terms of factors that influence the price of luminaires, no one factor was found to significantly affect pricing, but there were many: efficacy, lumens, watts, CRI, lifetime. This analysis was repeated in the 2018 pricing study and correlation factors were assigned and lumen output/wattage was determined to be the greatest influence on price. IOU LED deemed lighting measures have assumed that measure costs have scaled with efficacy, therefore this finding that efficacy may not be a key price driver implies that further analysis should be conducted to consider how to incorporate other price drivers in measure design to encourage the adoption of higher degrees of efficiency.

The projected LED price decline is expected to have a significant impact on LED adoption in California. The forecasted installed stock penetration of LEDs into the various outdoor applications was expected to increase from 11-19% in 2015 to 42-54% in 2018, and then increase further to 66-78% in 2020. IOU Programs can help accelerate this adoption curve and encourage the adoption of higher and highest efficiency products.

Market actors said that lumen equivalence was the single most important factor when selecting an LED. End users also considered light color and wattage equivalence when selecting an LED fixture. It will be important to research and understand how customers perceive lumen equivalence in LED fixtures and if there is bin jumping similar to what reportedly occurs with LED lamps – when market actors choose an LED that does not align with its rated wattage or lumen equivalent. This could have implications for measure structure and how lumen equivalency is defined between base case and measure case in future workpaper updates.

When Navigant considered the incidence of early retirement, the results showed that the majority of contractors and end users indicated that they are more likely to replace equipment before the end of useful life with LEDs. This suggests that LED decision making is unique and warrants additional research on ER and ROB baselines. The IOUs are considering incorporating early retirement measures into future workpaper updates to capture the additional energy savings potential in the market.



Figure : Willingness to replace equipment with LEDs before end of useful life, relative to other replacements (Source: California LED Workpaper Update Study, Navigant, August 2015)

Survey data and specifications on existing fixtures also indicate that LEDs replacing metal halides and linear fluorescents are not near the upper end of the LED wattage ranges in the May 2014 disposition. The Navigant study results and IOU program data analysis point out that the majority of program activity happens in the lower wattage ranges for PG&E and it would be advisable for IOUs to break these measure codes into narrower wattage ranges to more accurately capture savings.

This revision of the workpaper breaks the measure codes into smaller wattage ranges and separate outdoor lighting product categories to more accurately capture savings and going forward will also evaluate program data to better understand what wattage products customers are buying. This program information can then be used to more accurately calculate energy savings.

### 1.5.3 LED Non-Residential Lighting Market Characterization, Navigant – In Progress

This Statewide Non-Residential LED Market Characterization Study being conducted by Navigant Consulting, Inc was initially scoped in response to a June 26, 2015 workpaper disposition for PGECOLTG179 LED Ambient Commercial Fixtures and Retrofit Kits, seeking additional clarification on qualifying LED technologies for the IOUs. Its expected completion date is Q3 2018. In that decision, Commission Staff think it is unclear that the DLC QPL meets the requirements of incentivizing the top half of quality products in the non-residential lighting market. In that disposition, Commission Staff wrote the following:

*“However, the products covered by this work paper are not covered by the CEC standard and therefore must still be “products that are in the top half of quality on the market.” As added guidance along with the more general guidance provided by the Commission in the text of the Decision (at 79) that “Our goal, as in D.12-05-015, is to avoid offering incentives for lighting products that do not meet consumer expectations and result in a poor lighting experience, discouraging customers from investing in energy efficient lighting in the future.” It is unclear that the DLC listed products meet this requirement. The work paper shall be revised to include the process utilized by the PAs that will ensure that products offered meet the direction from D.12-11-015.”*

This market share study is an effort to determine the size of the non-residential LED market and the relative market share of products on the DLC QPL. The study is also developing a proposed definition of “quality” for non-residential lighting and will work with Commission staff to finalize this quality definition for future use in PA’s lighting portfolio.

This study has been expanded to include distributor surveys to determine the standard practice baseline for interior LED categories. These surveys will ask distributors about their current sales/purchase mix by lighting technology, including LEDs. They will ask about the last 12 months and the projected sales mix by lighting technology for each of the next five years. The sales data is being collected separately for each interior product category and also attempts to collect efficacy data within LED products being sold.

Until this study is completed, IOUs will use the DOE Lighting Facts database as a proxy for representing the LED market.

## 1.6 Data Quality and Future Data Needs

### 1.6.1 Standard Practice Baseline Studies

The California Investor-Owned Utilities are working on a standard practice baseline and workpaper update study for outdoor lighting per the 2017ExteriorLEDFixturesDisposition-BaselineClarifications-12Apr2017, Resolution E-4795, and SCE-16-C-C-0073\_0500804246\_Ext. LED Lighting, dated 02/15/2017. Results are expected to be completed and available for use by late 2018. PG&E has updated this workpaper (Revision 8) with an interim solution per the 2018 Outdoor Lighting Phase 1disposition until the standard practice baseline study results have been approved and published.

### 1.6.2 Inclusion of Early Retirement (ER)/Accelerated Replacement (AR) Measure Application Type

PG&E is currently investigating ER/AR measure application type offering for the next iteration of the workpaper. The analysis will be derived from reviewing ER custom applications with a focus on customer segment(s) and geographical location(s). Resolution E-4818 begins to set a framework for deemed program level ER adoption for Preponderance of Evidence. Additionally, the Track 2 Working Group’s report is waiting for adoption or incorporation of future Decisions and/or Proposals.

### 1.6.3 Product ID Collection Process

As part of the IOUs’ future data needs, a more robust process to collect product information from program data is being implemented. It has been an ongoing challenge to run data analytics on existing Program data due to model number discrepancies from rebate application invoices and the DLC QPL. In order to address this challenge, IOUs propose to collect the unique DLC product ID in rebate applications. This unique identifier has no variation and can easily be used to match product information from program data to the performance metrics of these products listed on the DLC QPL. Collecting this additional information will be helpful for future workpaper updates.

### 1.6.4 LightingFacts LED Database

LightingFacts offers many benefits as a data source for a full characterization of the LED market:

* Up-to-date product offerings
* Large sample size (~30,000 outdoor products)
* Product performance data previously accepted by CalTF and Ex-Ante Review team in the LED Troffer workpaper
* Ability to filter by year, so that older products could be excluded from the efficacy sampling
* Important distinctions by primary use: LightingFacts captures the lower LPW values typical of Wall-mounted LEDs on the market.

Unfortunately, the Department of Energy will be ending future funding for the LightingFacts label program. Other data sources will need to be considered in lieu of LightingFacts such as the data that will be collected for the Navigant LED Market Characterization study.

### 1.6.5 Cost Data Quality

The cost analysis to develop the base case and measure case costs for this workpaper revision contemplated data from several sources including:

1. PG&E Program Data
2. Navigant Data from the Price Tracker
3. Online pricing

As detailed below, these cost determination approaches did not yield reliable incremental measure costs. Until further analysis can be conducted, incremental measure costs have been determined based on existing deemed rebate levels PG&E launched on January 1, 2018, and will be applied for this revision only as an interim solution. This option is described in further detail in Section 4 on Base and Measure Costs.

**PG&E Program Data:** To perform cost analysis, one of the challenges with the data was acquiring the wattage, lumen output, and efficacy of the rebated fixture because the unique Product ID that matches with the listed DLC fixture has not yet been implemented as part of application processing. Additionally, some applications did not contain a manufacturer and model number as it might be tracked elsewhere. Since the manufacturer and model number is inconsistent from application to application, an approximate logic was used to match with the rebated fixture with the DLC list. From there, the wattage, lumen output, and efficacy of the rebated fixtures were acquired. Some of the excluded applications entries had wattages out of the range of the measure definitions or had other cost data quality issues. Other known or possible cost data quality issues include setting the material cost per unit equal to the rebates, incorporating the labor costs in the material costs, misreported quantities, and incorrect DLC manufacturing and model number matching. Spot checking was conducted; however, it is a manual and time intensive task. Invoices or receipts are scanned into the database electronically.

From a general overview of the data, it was observed that costs do correlate to lumens or wattage as indicated in the Navigant 2018 LED Pricing study: as wattage increases, the cost per fixture also increases. The data also points that when comparing efficacy of LEDs, the price premium may not exist and as such, efficacy does not largely drive the cost of the fixture. From recent discussions with the Commission Staff (early April 2018), a suggestion of cost pair matching was suggested. The idea of cost pair matching is to find a group of similar fixtures in terms of fixture features in the base case as well as the measure case. For example, if explosion proof, wet location rated, vibration resistant outdoor fixtures were found in the measure case, the base case should also possess the same fixture features. This will drop variables in the cost of a fixture and leave efficacy as the sole variable left contributing to the price delta. A first examination of pair matching was conducted based on a few manufacturers for all outdoor pricing, and the results can be seen in the table below:

Table : Sample Pair Matching by Manufacturer

|  |  |  |  |
| --- | --- | --- | --- |
| **Manufacturers** | **Premium** | **Standard** | **Adder for Premium** |
| CREE | $708.45 | $431.79 | $276.66 |
| Foshan | $396.50 | $540.01 | $(143.51) |
| Hubbell | $1,079.76 | $199.99 | $879.77 |
| Mester LED Limited | $223.84 | $227.50 | $(3.66) |

Detailed manufacturing cost pair matching can be found in the cost workbook on the “MFr-MatchPairs-StdVsPrem” tab. Further in-depth investigation will be needed to research the spec sheets of the rebated fixtures. This is a time intensive and manual task, which can be evaluated for the next iteration of the workpaper.

# Section 2. Calculation Methods

**Base Case Assumptions used in the Calculations**

**Technology Percentage Mix:** From the 2018 Outdoor Lighting Phase 1 Disposition, the base case technology mix is as listed in Table 1 Base Case Technology Percentage Mix.

**Linear Fluorescent:** Standard Fixture Wattages from Appendix B are used for fluorescent base case.

**Metal Halide:** Standard Fixture Wattages from Appendix B are used for Metal Halide base case power consumption (except where superseded by Title 20MH regulation). Metal Halide lamp light output data was taken from a Lighting Resource Center survey of MH: *LRC Lighting Answers: Mid-wattage Metal Halide Lamps,[[12]](#endnote-13)* and from product catalog data. This information is shown on the “Lumens Match” tab in the calculations spreadsheet.

Table 13 Metal Halide Initial Lamp Output

|  |  |
| --- | --- |
| **Nominal Lamp Wattage** | **Average Lumens** |
| 70 | 5,108 |
| 100 | 8,213 |
| 150 | 12,360 |
| 200 | 20,000 |
| 250 | 23,183 |
| 320 | 30,473 |
| 400 | 42,250 |
| 750 | 75,000 |
| 1000 | 120,000 |

**LED:** The LED base case power consumption was based on performance from the DOE LightingFacts database.[[13]](#endnote-14) The 25th percentile efficacy of the sample was used to estimate performance of the base case LED fixtures as a reasonable assumption when without efficiency incentive programs promoting higher-efficacy products customers are likely to select products from the non-certified lower-efficacy half of the market products. A sample of nearly 30,000 products in the LightingFacts database representing all submissions over the last 2 years was broken down by Primary Use (Street/Road/Area, Garage, Canopy, and Wall-Mounted). The disposition provided a percentile efficacy breakdown by lumen output bins as shown highlighted in the following tables or in the savings spreadsheet on the Lighting Facts-LEDBase tab:

Table Lighting Facts 25th Percentile for Wall-Mounted, Area/Roadway, Canopy, and Parking Garages by Light Output Corresponding to Measure Wattage Bins









**Measure Case Assumptions used in the Calculations**

The measure case for all outdoor lighting are 100% LED based on the Premium Technical Requirements version 4.3 of the DesignLights Consortium2 (DLC), including an efficacy of at least 130 lumens per watt.

**Representative Fixtures and Factors Used in Calculations**

LED fixtures were assigned an equivalent maintained, useful light output to the Metal Halide fixture in order to ensure equivalent level of service being achieved in the base case. A one-for-one relationship was also established for that comparison purpose. Metal halide fixture efficiency and light distribution information for both LED and Metal Halide were taken from photometric data in the form of “.ies” files obtained from manufacturer websites. Not all manufacturer websites offered photometric files for download, but model numbers from current program application were used to try to match the selected fixtures in the calculations with those in common use. These standard report files were loaded into the online Photometric Viewer from Acuity Brands’ Visual 3d software to produce uniform light distribution reports listing efficacy and lumens by zone. LED fixtures reported 100% efficacy in all .ies reports, as is standard for absolute photometric measurements.

Light depreciation for LED fixtures (both base and measure case) was assumed to be 30% in keeping with exterior hours of use over the 12-year DEER measure life and the DLC minimum of a 50,000 hour L70 (i.e. the point of 30% lumen depreciation). The base case LED and measure case DLC-Premium LEDs were assumed to have identical light outputs and lumen maintenance differing only in efficacy and wattage.

For garage lighting only, the Lumen Maintenance assumptions for fluorescent and metal halide fixtures were based on Pacific Northwest National Laboratories’ 2013 report, Lumen Maintenance and Light Loss Factors: Consequences of Current Design Practices for LEDs.[[14]](#endnote-15) Fluorescent fixtures were matched to Metal Halide fixtures of approximately similar light output due to the challenge of 1-to-1 matching, given fixed values for lamp light output.

Initial metal halide lamp light outputs for each lamp wattages chosen, and for primary use category were reduced by the following factors:

* Fixture efficiency based on actual manufacturer-published photometric data
* Lamp lumen maintenance: 58% for all metal halide based on end-of-life output and not mean lumen output, typical of quartz metal halide lamps.

Table Lumen Maintenance Assumptions by Source Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Fluorescent Base Case Value** | **MH Base Case Value** | **LED Base Case Value** | **LED Measure Case Value** |
| 92% | 58% | 70% | 70% |

**Delta Wattage Assumption (ΔW)**

This section describes the method used to match MH base case fixtures to equivalent LED fixtures used in the previous submittal of the workpaper and used the same method for the interim solution. The LED fixtures being matched include both base case and measure case, and the calculations assume no difference in the light distribution, lumen maintenance, or fixture efficiency between the base and measure case LEDs.

Between LED and MH, however, significant differences in light distribution exist and due to these differences, the service provided by a MH fixture of a certain lumen output is not equivalent to the service provided by an LED fixture of the same lumen output. PG&E lighting workpapers have previously considered the differential benefit of lighting distribution, both in previous revisions of this workpaper PGECOLTG151 where DOE Gateway field studies were used to justify uniformity improvements.

For Exterior products, however, the Zonal Lumen requirements of the DLC are much broader, and thus less useful in distinguishing good fixture performance. Those requirements are reproduced in the table below.

Table DLC v 4.3 Light Output and Zonal Lumens Distribution

|  |  |  |  |
| --- | --- | --- | --- |
| **Primary Use Designation** | **Minimum Light** **Output (lm)** | **Zone Definition** | **Zonal Lumen** **Requirement** |
| Outdoor Pole/Arm-Mounted Area and Roadway Luminaires | 1,000 | 0-90⁰ | 100% |
| 80-90⁰ | ≤10% |
| Outdoor Pole/Arm-Mounted Decorative Luminaires | 1,000 | 0-90⁰ | ≥65% |
| Outdoor Full-Cutoff Wall-Mounted Area Luminaires | 300 | 0-90⁰ | 100% |
| 80-90⁰ | ≤10% |
| Outdoor Non-Cutoff and Semi-Cutoff Wall-Mounted Area Luminaires | 300 (0-90° zone)\*\*\* | 80-90⁰\*\*\* | ≤10%\*\*\* |
| Parking Garage Luminaires | 2,000 | 60-80⁰ | ≥30% |
| 70-80⁰ | ≤25% |
| Fuel Pump Canopy Luminaires | 2,000 | 0-40⁰ | ≥40% |
| 40-70⁰ | ≥40% |

The requirements generally encourage light output in the zone between 0 and 70 or 80 degrees from nadir, and discourage light above 80 or 90 degrees from nadir, but these requirements alone do not distinguish the best-performing fixtures: those that distribute light across the widest area with the most uniformity.

By this definition of “best-performing,” MH and other HID fixtures have a widely acknowledged shortcoming. They are known for creating pools of light underneath the fixtures with much darker sections between. This effect is well-known in social science research.[[15]](#endnote-16) For the purposes of illuminating outdoor spaces, the important point is that the pool of light under the fixture would be much more useful were it to be spread more evenly across the outdoor environment. The Illuminating Engineering Society’s list of Recommended Practices and Illuminance Guidelines has formalized this suggestion for uniform outdoor and garage illuminances in various documents:

Table IES Recommended Practice for Outdoor Lighting

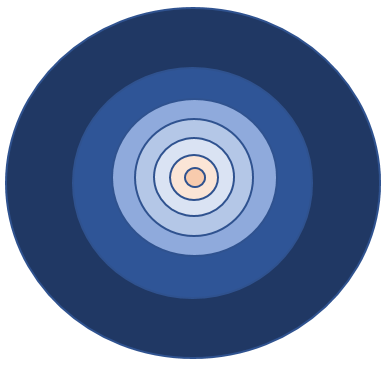
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Max/Min Ratio** | **Avg/Min Ratio** | **Max/Avg Ratio** | **Source** | **Calculated Max/Min Ratio** |
| Canopy | - | 4 | 2 | IES handbook 10th ed., p 34.28-31. Table 34.2: 'Dispensing Islands' | 8 |
| Garage | 10 | - | - | IES handbook 10th ed., p 26.19 | 10 |
| Road & Area | 7.2 | - | - | IES RP-8-14: Roadway Lighting, p13. Tables 3: Design Criteria for Streets: average of all uniformity ratios | 7 |
| Wall-Mounted | - | 2 | 3 | IES RP-33-14: Exterior Environments, p.11. Table 2a: Building Entries, non-covered, immediate Exterior | 6 |

For all types of outdoor lighting, light distribution patterns create bright and dark areas such that the average illuminance is above a certain threshold are less useful. The lumen output creating the bright areas would be useful if it could be spread out to brighten the darker areas, but this is difficult due to the challenges in precisely controlling the output of a larger omnidirectional light source such as a MH lamp. The implication is that bright areas underneath outdoor fixtures are due to light output at an angle where it is not useful, and the savings calculations for this workpaper aim to discount this non-useful output.

This workpaper uses the uniformity definition above, plus light output data from common outdoor fixtures, to quantify the “Useful Light Output” of representative Metal Halide and LED fixtures. To determine what is and is not useful, the savings calculation assumes that the fixtures are illuminating a large horizontal plane, and uses a trigonometric analysis of fixture performance. Fixture manufacturers commonly provide light output data for their fixtures organized by zones representing every 10 degrees from nadir, the direction down from the fixture toward the horizontal task plane, as in this example.

Table Lumens Per Zone

|  |  |  |
| --- | --- | --- |
| **ZONE (degrees)** | **LUMENS** | **% TOTAL** |
| 0-10 | 330.0 | 3.5% |
| 10-20 | 953.0 | 10.0% |
| 20-30 | 1,462.5 | 15.4% |
| 30-40 | 1,792.3 | 18.8% |
| 40-50 | 1,879.3 | 19.7% |
| 50-60 | 1,640.6 | 17.2% |
| 60-70 | 1,054.0 | 11.1% |
| 70-80 | 374.6 | 3.9% |
| 80-90 | 34.7 | 0.4% |



The zones, as they appear on the horizontal task plane, are rings or concentric circles of increasing diameter. The distance between perimeters of adjacent circles also increases as the circles broaden. This diagram shows the circles representing every zone in the above table from 0-10 degrees up to 60-70 degrees, in relative proportion. Angles greater than 70 degrees are not included further in the analysis, on the assumption that at angles 65 degrees and greater the reference point is so far from the fixture that an adjacent fixture is closer. A zonal lumen table like the one above can be used to determine the total light output from the fixture incident on each color ring and the average illuminance within each ring by dividing by the geometric area. Since the model is based only on the angles and lumen percentages above, changing the assumed height of the fixtures does not change the illuminance in one ring relative to another. Only the illuminance measured in lux of foot-candles and the scale of the rings would change. Below is a graph of the illuminances by ring for LED and MH fixtures in units relative to the illuminance in the outer ring.

Figure 3 Diagram Representing Zones from 0-10° up to 60-70° in Relative Proportion

Figure Horizontal Illuminance by Angle From Nadir

The graph shows numerically the pool of light below the MH fixture. The illuminance at 5 degrees is more than 80 times the illuminance at 65 degrees. Comparatively, the LED illuminance curve is quite flat, a relatively uniform light distribution.

Figure 3 graph looks just at the MH fixture distribution, and zooms in on the bottom third of the vertical axis. The average illuminance across the area is graphed. It is not the numerical average of the values from 5 to 65 degrees, but rather the average per unit area across all rings. The areas of the outer rings are much larger than the areas of the inner rings, so they contribute much more to the average.

The minimum illuminance from a single fixture in the defined area is 1. This is the unit used for illuminance in this example. At the point where two fixtures are 65 degrees from overhead, two fixtures are equidistant from the point of measurement, so the assumed minimum illuminance is 2. The average illuminance in the area is 2.9, which close to the IES-recommended ratio between average and minimum for certain roadway applications. Illuminances are much higher closer toward the center, but above a certain level increasing illuminance is not useful. It is actually harmful to the visual task at hand in creating challenges of visual accommodation—the adjustments needed in the eye as the observer moves from dark to light to dark areas. This workpaper is assuming that illuminances above the appropriate Maximum-to-minimum ratio are not contributing visual benefit. The light output that is Useful is represented by the shaded area of illuminance graph in Figure 3. The lumens contributing to very high illuminances above the Useful threshold line are not counted as Useful lumens. Above this threshold, greater illuminance is not “Useful” and only creates bright spots.

Figure Magnified View of Horizontal Illuminance by Angle From Nadir

The formulas for calculating useful lumens in each zone and total useful lumens are the following:

Useful lumens in a zone = the total fixture lumens in the zone multiplied by the ratio of useful illuminance to actual horizontal illuminance, with the ratio being capped at 1.

Fixture Useful lumen = the sum of “Useful lumens in each zone” from zero through 80 degrees from nadir.

Most fixture types consider 70 degree spacing as typical, but for Fuel Canopy fixture types, which are typically close together with light directed downward, a 30 degree spacing is used.

LED fixtures perform better than MH fixtures in the percentage of light output deemed “Useful” by this metric, as they are typically composed of an array of LED chips, each of which may be aimed separately and precisely where needed for the sake of uniformity. Evaluating common metal halide fixture uniformity shows that 24% of common road and area fixture light output, and 45% of wall-mounted fixtures light output may not be useful. For LEDs, with much better directional light control and uniformity, the figures are 7% and 34%, based on actual fixtures from PG&E application data in current programs. As shown above, different fixture types have varying percentages of Useful lumens, most notably wall-mounted fixtures, where the light must also be directed away from a wall.

Returning to the task of matching LED fixtures to equivalent MH base case fixtures, the workpaper assumes 1-to-1 equivalence of Useful lumens according to the calculation above. For each fixture type and MH lamp wattage, the LED fixture light outputs closest to equivalence were determined, accounting for Useful Lumens, Lumen Maintenance, and Fixture Efficiency.

The LED measure case wattage ranges were determined by dividing the lumen output ranges by the DLC Premium-Classification minimum efficacies. The Delta Watts are simply the LED measure case minus the blended average of base case LED, Metal Halide, and Fluorescent (only for garages) wattages.

**Calculation Method Process**

For example, for a Street light with a 70W MH lamp of 5,108 lumens, various factors as shown in the table below were used to calculate the equivalent LED wattage.

Table Adjustment Factors for Streetlight

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Fixture Type** | **Representative Performance** | **Fixture Eff** | **Useful Lumens** | **Maintained lm** | **LED Depreciation** | **LED Useful Lm** |
| Streetlight | Std Horiz | 70.3% | 76.3% | 58.0% | 70.0% | 92.6% |

Table Calculated Lumens

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Lamp Nominal W** | **Fixture Eff** | **Useful Lumens** | **Maintained lm** | **LED Depreciation** | **LED Useful Lm** |
| Streetlight | 70 | 3,592 | 2,741 | 1,590 | 2,271 | 2,454 |

1. 70.3% fixture efficiency means that 3,592 lumens will exit the fixture.
2. 76.3% Useful lumens means that 2,741 lumens will contribute usefully to the task plane (and 23.7% of lumens will fall above 80 degrees or contribute to a bright spot below the fixture or end up at angles greater than 80 degrees)
3. 58.0% lamp depreciation means that 1,590 lumens will remain at end-of-life.
4. 1,590 is also the number of Useful lumens that are assumed for the end-of-life LED fixture
5. At 70.0% lumen maintenance at end-of-life, the initial Useful lumen output is assumed to be 2,271
6. Because 92.6% of the LED lumens are Useful, the initial fixture light output is assumed to be 2,454.
7. For a 100W MH lamp, the next higher wattage, the corresponding initial LED fixture output is 3,946.
8. Picking the midpoint between the two values and rounding to the nearest ten, 3,200 lumens is picked as the dividing point between 70- and 100W-equivalent LED fixture initial light outputs.
9. Dividing 3,200 lm by 110 lm/W yields 29W, the value corresponding to the upper end of the wattage range for 70W MH fixtures.

Table Wattage bin for the LED Streetlight for 70W

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **DLC Premium LPW** | **DLC Premium Lm Min** | **DLC Premium Lm Max** | **Min LED W** | **Max LED W** |
| 110 | 0 | 3,200 | 0 | 29 |

Note: For the wattage bin calculations of all other measures, see the savings calculation spreadsheet “Outdoor Lighting Savings Calculations” that accompanies this workpaper on the “Lumens Match” tab.

## 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 watts/ unit*

*Annual Electric Savings:*



The following example calculates the annual electric energy kWh savings for the “LED Street/Outdoor Area Lighting - Install 0-29 W Fixture” measure:



For the savings of all other measures, see the “Outdoor Lighting Savings Calculations” that accompanies this workpaper.

## 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 is no gas energy saving 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 Cost Effectiveness Tool (CET) 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 CET 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 Building Type and Load Shape

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

# Section 4. Base Case & Measure Costs

Due to cost challenges listed in Section 1.6.6 Cost Data Quality, three cost options were evaluated. For the interim solution, cost option 3 was agreed upon with Commission Staff and until further research can be completed for cost pair matching. The options are listed below along with the advantages and disadvantages associated with each option:

* **Option 1:** The base case LED cost is calculated using an average of the DLC Standard fixtures obtained from PG&E Program Data, webscraped data, and/or Navigant data.
  1. **Advantages:** The incremental cost values are all positive except for 4 measures.
  2. **Disadvantages:** Efficacy does not mirror the savings base case efficacy.
* **Option 2:** The base case LED cost is calculated using an average of the fixtures with an efficacy at or below the DOE LightingFacts 25th percentile obtained from PG&E Program Data webscraped data, and/or Navigant data.
  1. **Advantages:** The efficacy mirrors the savings base case efficacy.
  2. **Disadvantages:** Even with a projected annual percent decline percentage applied, the cost is still high and therefore, creating negative incremental cost values. There are 9 instances where the LED base case cost is higher than the measure case cost.
* **Option 3:** Acknowledges the traditional cost logic model should be re-evaluated and as an interim solution, establishes the IMC based on the proposed rebates for the program.
  1. **Advantages:** Minimizes disruption to program participants enabling existing measures launched on January 1, 2018 can continue, reflecting baseline and savings adjustments
  2. **Disadvantages:** Lack of supporting data

## 4.1 Base Case(s) Costs

**Option 1 and 2:** Pricing was determined from 3 sources for current base case costs for the applications defined in this work paper.

1. LED & MH Pricing Analysis by Navigant Consulting based on online pricing, with sources noted.
2. Online pricing collection by the workpaper engineering team.
3. Analysis of 2017 PG&E program data (rebate and incentive invoices) conducted November 2017.

See Table 11 Base Case Technology Percentage Mix which was applied to arrive at the final base case cost. For pricing on all measures, see the “Outdoor WP Cost Data” spreadsheet that accompanies this workpaper.

**Option 3:** The base case cost is set temporarily at $0.

## 4.2 Measure Case Costs

**Option 1 and 2:** Pricing was determined from 3 sources for current measure case costs for the applications defined in this work paper.

1. LED Pricing Analysis by Navigant Consulting based on online pricing with sources noted.
2. Online pricing collection by the workpaper engineering team, with sources noted.
3. Analysis of 2017 PG&E program data (rebate and incentive invoices) conducted November 2017.

The labor cost used is $187.14 per WO017 for lift accessible fixtures[[16]](#endnote-17). For pricing on all measures, see the “Outdoor WP Cost Data” spreadsheet that accompanies this workpaper.

**Option 3:** The measure case cost is set equal to the incremental measure costs.

## 4.3 Incremental & Full Measure Costs

**Option 1 and 2:** Establishing prices for each measure code presented a challenge, given the wide range of price, quality, and product characteristic in the outdoor lighting market. The general approach used was to gather prices widely and look at overall trends in price, because a sampling relying strictly on matching products to one of 50 measure codes is prone to sampling error when particularly expensive or inexpensive products are sampled.

The Cost data workbook has the gathered price, output, and wattage characteristics for each category of fixtures separately, and LED prices separate from Metal Halide (and from fluorescent, for Garage fixtures). A total of more than 2000 LED price samples were separated into measure case (DLC Premium, or Navigant “DLC” plus efficacy >130 LPW where Premium information was not collected). The linear trendline best fit of price was determined for each group: 1) for measure and base case LEDs based on light output, which the Navigant data suggested was the most strongly correlated variable with price, and 2) for Metal Halide based on wattage.

Garage MH and Fluorescent data were not collected by Navigant, so base cases were determined by sampling alone for Garages without trending analysis.

**Option 3:** The incremental measure cost is set to 110% of the rebate amount.

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 for all options, see the Cost data spreadsheet that accompanies this workpaper.

# Attachments

Outdoor WP InterimSolutionSavings Data-20180411.xlsx

Outdoor WP InterimSolutionCost Data-20180411.xlsx

PGECOLTG151 R8 InterimSolution EDReport.xlsx

# References

1. DesignLights Consortium. *Qualified Products List.* NEEPDLCQPL.xls [↑](#endnote-ref-2)
2. DesignLights Consortium. *Technical Requirements Table v4.3.* <https://www.designlights.org/default/assets/File/SSL/DLC_Technical-Requirements-V-4-3.pdf>

   *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. CALiPER Snapshot Outdoor Area Lighting. DOE. September 20, 2017. <https://www.energy.gov/sites/prod/files/2017/10/f37/snapshot2017_outdoor-area.pdf> [↑](#endnote-ref-4)
4. 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-5)
5. The table “Measure Application Type” in the Measure Catalog can be found on the Database for Energy-Efficient Resources (DEER) website [www.deeresources.com](http://www.deeresources.com)*.* [↑](#endnote-ref-6)
6. California Energy Commission *Title 20: California Appliance Regulations* 2016. <http://www.energy.ca.gov/2016publications/CEC-140-2016-001/CEC-140-2016-001-REV3.pdf> [↑](#endnote-ref-7)
7. DOE *Energy Conservation Standards for Metal Halide Lamp Fixtures; Final Rule.* <https://www.regulations.gov/document?D=EERE-2009-BT-STD-0018-0072> [↑](#endnote-ref-8)
8. 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-9)
9. 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-10)
10. Navigant Consulting. *California LED Pricing Analysis – Final Draft.* January 2018. <http://www.calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_Final.pdf> [↑](#endnote-ref-11)
11. Navigant Consulting. California LED Workpaper Update Study – Final Report. August 28, 2015. <http://www.calmac.org/publications/LED_Study_Report_FINAL_201510029.pdf> [↑](#endnote-ref-12)
12. Lighting Research Center. *Lighting Answers: Mid-wattage Metal Halide Lamps.* Accessed at <http://www.lrc.rpi.edu/programs/nlpip/lightinganswers/mwmhl/characteristics6.asp> [↑](#endnote-ref-13)
13. DOE *Lighting Facts Database.* September 26th, 2017.http://lightingfacts.com/Products [↑](#endnote-ref-14)
14. DOE and Pacific Northwest National Laboratory (PNNL). *Lumen Maintenance and Light Loss Factors: Consequences of Current Design Practices for LEDs*, page 3. <http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22727.pdf> [↑](#endnote-ref-15)
15. [David H. Freedman](https://en.wikipedia.org/w/index.php?title=David_H._Freedman&action=edit&redlink=1) (August 1, 2010). ["The Streetlight Effect"](http://discovermagazine.com/2010/jul-aug/29-why-scientific-studies-often-wrong-streetlight-effect). [*Discover magazine*](https://en.wikipedia.org/wiki/Discover_magazine). <http://discovermagazine.com/2010/jul-aug/29-why-scientific-studies-often-wrong-streetlight-effect>.

    [↑](#endnote-ref-16)
16. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Submitted by: Itron, Inc. May 27, 2014. Page 4-12. [↑](#endnote-ref-17)