



436 14th St., Suite 1020, Oakland, CA 94612
Phone: (510) 400-5374
Email: MGoebes@trcsolutions.com

Exterior Lighting Standard Practice Baseline and Work Paper Support – Final Report

December 31, 2018



Submitted to Southern California Edison

Reginald Wilkins
1515 Walnut Grove Ave.
Rosemead, CA 91770

Submitted by TRC

Marian Goebes
Michael Mutmansky
Cathy Chappell
Lake Casco
Nolan Stephens
Julia Sinex
Neil Perry
Srushti Koli
David Lu (ASWB Engineering)



TABLE OF CONTENTS

- 1. EXECUTIVE SUMMARY 9**
 - 1.1 Standard Practice for Exterior Lighting Sales and Projections9
 - 1.2 Comparison of Standard Practice to Title 24 11
 - 1.3 Installed Exterior Lighting 11
 - 1.4 The Maintenance Market and Barriers to Retrofits 12
 - 1.5 Recommendations 12
- 2. INTRODUCTION..... 14**
 - 2.1 Overview and Purpose 14
 - 2.2 Terminology and Dual Baseline Description 14
 - 2.3 Background – Summary of Related CPUC Dispositions 16
 - 2.4 Research Questions 18
 - 2.5 Product Categories for Investigation 19
 - 2.6 Structure of Report 19
- 3. METHODOLOGY 20**
 - 3.1 Overview of Data Collection 20
 - 3.2 Market Actor Survey Methodology..... 21
 - 3.2.1 *Lighting Market Actor Contact Identification* 21
 - 3.2.2 *Recruitment*..... 21
 - 3.2.3 *Survey Dispositions*..... 22
 - 3.2.4 *Survey Guide* 23
 - 3.2.5 *Weights for Survey Results*..... 24
 - 3.3 Pricing and Efficacy Data Collection 26
 - 3.3.1 *Data from Manufacturers Reps* 26
 - 3.3.2 *Online Sales Channels* 27
 - 3.3.3 *Pricing model and DLC verification* 28
 - 3.4 Calculation of Standard Practice Efficacy and Pricing..... 28
 - 3.5 Comparison of Efficacy and Code 29
 - 3.6 Methodology for Developing Model of Installed Exterior Lighting 30
 - 3.7 Projections 33
- 4. ANALYSIS AND RESULTS 34**
 - 4.1 Current and Projected Penetration of LEDs 34
 - 4.1.1 *Standard Practice by Technology*..... 34

- 4.1.2 *Projections of LED Market Penetration* 36
- 4.2 Standard Practice LED Efficacy and Pricing 37
 - 4.2.1 *Efficacy Ranges for Available Products* 37
 - 4.2.2 *Pricing Ranges for Available Products*..... 38
 - 4.2.3 *Sales by DLC Designation* 44
 - 4.2.4 *Standard Practice for LED Fixture Efficacy* 45
 - 4.2.5 *Standard Practice Pricing* 46
- 4.3 Efficacy projections for 2019 - 2023 47
- 4.4 Price Projections for 2019 - 2023..... 49
 - 4.4.1 *Price per Lumen Comparison*..... 50
 - 4.4.2 *Pricing Comparison in Navigant and TRC Data Sets*..... 50
 - 4.4.3 *Price Projections*..... 51
- 4.5 Comparison of Standard Practices and Title 24-2019 Requirements 53
- 4.6 Installed Stock by Technology 55
 - 4.6.1 *Results of TRC’s Model of Installed Exterior Lighting* 55
 - 4.6.2 *Market Actor Survey Responses of Technologies Retrofitted* 58
 - 4.6.3 *Comparison of Results to Literature Review Findings of Installed Exterior Technologies*
60
- 4.7 Lamp Replacement (Maintenance) Market and Barriers to Retrofits..... 64
 - 4.7.1 *Barriers to Retrofits*..... 64
 - 4.7.2 *Size of Replacement Market* 64
 - 4.7.3 *Example of Base Case Measure Cost and IMC if Maintenance Incorporated* 65
- 5. CONCLUSIONS**..... **67**
 - 5.1 Standard Practice for Exterior Lighting Sales and Projections 67
 - 5.2 Installed Exterior Lighting..... 68
 - 5.3 The Maintenance Market and Barriers to Retrofits 69
 - 5.4 Recommendations 69
- 6. REFERENCES** **71**
- 7. APPENDIX**..... **72**
 - 7.1 Methodology for Identifying Lighting Market Actor Contacts..... 72
 - 7.1.1 *Manufacturers* 72
 - 7.1.2 *Manufacturer Reps* 72
 - 7.1.3 *Maintenance Contractors* 72
 - 7.2 Manufacturer Survey Responses 72
 - 7.2.1 *Sales by Technology* 72

7.2.2	<i>DLC designation and Efficacy for LED sales</i>	73
7.2.3	<i>Projections of LED Penetration</i>	75
7.2.4	<i>Existing Products</i>	75
7.3	Manufacturer Rep Survey Responses	76
7.3.1	<i>Sales by Technology</i>	76
7.3.2	<i>DLC Designation and Efficacy for LED sales</i>	77
7.3.3	<i>Projections of LED Penetration</i>	79
7.3.4	<i>Replaced Technologies</i>	80
7.3.5	<i>Barriers to Exterior Lighting Retrofits</i>	81
7.4	Maintenance Contractor Survey Responses	81
7.4.1	<i>Installations by Construction Type</i>	81
7.4.2	<i>Installations by Technology</i>	83
7.4.3	<i>DLC Designation for LED Installations</i>	84
7.4.4	<i>Projections of LED Penetration</i>	85
7.4.5	<i>Replaced Technologies</i>	85
7.4.6	<i>Barriers to Retrofits and Lamp Replacements</i>	86
7.5	Market Actor Estimates of Sales by DLC Designation for each Product Category	86
7.6	Product Pricing and Efficacy Results	89
7.6.1	<i>Product Efficacy Results</i>	89
7.6.2	<i>Product Pricing Results</i>	91
7.6.3	<i>Analysis of Price versus Lumen Output</i>	93
7.6.4	<i>Analysis of Efficacy versus Wattage</i>	96
7.6.5	<i>Projected Fixture Efficacy by Product Type and DLC Classification</i>	100
7.7	Literature Review Estimates of Installed Fixtures	101
7.7.1	<i>Commercial Building Stock Assessment (NEEA 2016)</i>	101
7.7.2	<i>California Commercial Saturation Survey (Itron 2014)</i>	103
7.7.3	<i>US Lighting Market Characterizations (DOE 2017a)</i>	105
7.8	NEMA Lamp Indices (2011-2018)	106
7.9	Survey Guide	108

TABLE OF FIGURES

Figure 1: Illustration of Lifetime Savings Calculation for ER Measures Using a Dual Baseline.....	16
Figure 2: 2018 Non-DLC Qualified Lighting Product Efficacy by Output Group.....	37
Figure 3: 2018 DLC Standard Qualified Lighting Product Efficacy by Output Group.....	37
Figure 4: 2018 DLC Premium Qualified Lighting Product Efficacy by Output Group.....	38
Figure 5: 2018 Non-DLC Qualified Lighting Product Price by Output.....	38
Figure 6: 2018 DLC Standard Qualified Lighting Product Price by Output.....	39
Figure 7: 2018 DLC Premium Qualified Lighting Product Price by Output.....	39
Figure 8: 2018 Price versus Output: Streetlight	43
Figure 9: 2018 Wattage versus Efficacy: Streetlight	43
Figure 10: 2018 Standard Practice Efficacy Estimate by Product Category.....	46
Figure 11: 2023 Non-DLC Qualified Lighting Product Efficacy by Output Group	48
Figure 12: 2023 DLC Standard Qualified Lighting Product Efficacy by Output Group.....	48
Figure 13: 2023 DLC Premium Qualified Lighting Product Efficacy by Output Group.....	49
Figure 14: 2023 Non-DLC Qualified Lighting Product Price by Output	52
Figure 15: 2023 DLC Standard Qualified Lighting Product Price by Output.....	53
Figure 16: 2023 DLC Premium Qualified Lighting Product Price by Output	53
Figure 17: Estimated Number of Exterior Lighting Products Installed in California, by Technology	55
Figure 18: Estimated Number of Exterior Lighting Products Installed in California, HID Technologies Aggregated	56
Figure 19: Estimated Electricity Use of Exterior Lighting Installed in California, by Technology...	57
Figure 20: Manufacturer 5-Year LED Projection	75
Figure 21: Manufacturer Rep Projections of LED Penetration	79
Figure 22: Price versus Output: Streetlight Fixtures	93
Figure 23: Price versus Output: Pole Mount.....	93
Figure 24: Price versus Output: Wall Mount.....	94
Figure 25: Price versus Output: Floodlight	94
Figure 26: Price versus Output: Bollard	95

Figure 27: Price versus Output: Fuel Canopy 95

Figure 28: Price versus Output: Parking Garage 96

Figure 29: Efficacy versus Wattage: Streetlight 96

Figure 30: Efficacy versus Wattage: Pole Mount 97

Figure 31: Efficacy versus Wattage: Wal Mount 97

Figure 32: Efficacy versus Wattage: Floodlight 98

Figure 33: Efficacy versus Wattage: Bollard 98

Figure 34: Efficacy versus Wattage: Fuel Canopy 99

Figure 35: Efficacy versus Wattage: Parking Garage 99

Figure 36: Outdoor Lighting Power by Technology: Commercial and Industrial (NEEA 2016)..... 102

Figure 37: Outdoor Lighting Power by Technology – Walkways / Area Lighting (NEEA 2016) 102

Figure 38: Outdoor Lighting Power by Technology – Parking Lots (NEEA 2016) 103

Figure 39: Outdoor Lighting Power by Technology – Parking Garage (NEEA 2016) 103

Figure 40: Outdoor Lighting: Distribution of Lamps by Technology (EE Lighting Non-Participant) 104

Figure 41: Outdoor Lighting: Distribution of Lamps by Technology (EE Lighting Participant) 104

Figure 42: Estimated Inventory of Lamps by Technology - Parking Lots & Garages (DOE 2017a) 105

Figure 43: Estimated Inventory of Lamps by Technology – Roadways (DOE 2017a) 105

Figure 44: Lamp Sales Indices for Linear Fluorescent Lamps (NEMA) 106

Figure 45: Linear Fluorescent and Tubular LED (TLED) Shipments – Percent by Technology (NEMA)
..... 107

Figure 46: HID Lamp Sale Indices (NEMA) 107

TABLE OF TABLES

Table 1: Estimate of Installed Exterior Lighting Products and their Electricity Use in California in 2018 and 2023	11
Table 2: Key Terms.....	14
Table 3: Research Questions	18
Table 4: Data Collection Activities Mapped to Research Questions	21
Table 5: Survey Dispositions by Respondent Type	22
Table 6: Manufacturer Rep and Contractor Surveys by IOU Territory	22
Table 7: Manufacturer Weights	24
Table 8: Manufacture Rep Weights	25
Table 9: Maintenance Contractor Weights	25
Table 10: Weights across Market Actors	25
Table 11: Number of Products in Manufacturer Rep Data Set for Pricing and Efficacy.....	27
Table 12: Number of Products in Online Data Set of Product Pricing and Efficacy	28
Table 13: DLC Classifications by Output.....	29
Table 14: Retrofit Rate Assumptions in Exterior Lighting Replacement Model	30
Table 15: Assumed Lamp Life Hours and Replacement Technology in Exterior Lighting Replacement Model.....	32
Table 16: Market Actor Exterior Fixture Sales by Light Source Technology	34
Table 17: Market Actor Exterior Fixture Sales of LED Products, for each Product Category.....	35
Table 18: Projections of LED Penetration by Market Actor.....	36
Table 19: National Projection of LED Penetration for Outdoor Lighting (DOE, 2014).....	36
Table 20: 2018 Pricing Results by DLC Designation: Streetlight and Pole Mount Fixtures	40
Table 21: 2018 Pricing Results by DLC Designation: Wall-mount and Floodlight Fixtures.....	41
Table 22: 2018 Pricing Results by DLC Designation: Bollard and Fuel Canopy Fixtures.....	41
Table 23: 2018 Pricing Results by DLC Designation: Parking Garage	42
Table 24: Market Actor Estimates of Sales by DLC Designation for all Exterior Lighting Fixtures	44
Table 25: 2018 Standard Practice Efficacy Estimate by Product Category	45
Table 26: 2018 Standard Practice Pricing Estimate by Product Category	46

Table 27: National LED Efficacy Projections (DOE 2014)..... 47

Table 28: LED Package Efficacy Projections (DOE 2017b)..... 47

Table 29: LED Efficacy Projections for 2023..... 47

Table 30: Price Decrease Compared to Previous Year, Assumed by Navigant (2018) 49

Table 31: Price per kLm in Navigant Data, TRC Data, and DOE Projections: Streetlight, Pole Mount, Wall Mount and Floodlight..... 50

Table 32: Price per kLm in Navigant Data, TRC Data, and DOE Projections: Bollard, Fuel Canopy, and Parking Garage Fixtures..... 50

Table 33: Pricing Comparison for Identical Products: Current Pricing (Q3 2018) Compared with Navigant Pricing (Collected Q2 2016 - Q4 2017) 51

Table 34: LED Fixture Price Change Compared to Previous Year Used for Price Projections..... 51

Table 35: Price Projections for 2023 Exterior Lighting Products..... 52

Table 36: Title 24-2019 Efficacy Comparison for Pole Mount Category..... 54

Table 37: Title 24-2019 Efficacy Comparison to TRC Standard Practice Findings 54

Table 38: Estimated Percentage of Exterior Lighting Fixtures Installed, by Technology 57

Table 39: Replaced Technologies in Exterior Retrofits, as Reported by Manufacturer Reps..... 59

Table 40: Replaced Technologies in Exterior Retrofits, as Reported by Maintenance Contractors.....60

Table 41: Product Categories Covered in Published Studies of Installed Lighting 61

Table 42: Comparison of Installed Stock and Replaced Technologies 62

Table 43: Number of Market Actors that Cited Cost as Barrier to Retrofit 64

Table 44: Standard Practice Efficacy Estimate by Product Category..... 68

Table 45: Estimate of Installed Exterior Lighting Products and their Electricity Use in California in 2018 and 2023..... 69

Table 46: Number of Manufacturers Surveyed that Produce each Product Category 73

Table 47: Manufacturer Sales by Technology..... 73

Table 48: Manufacturer Sales by Technology, by Product Category 73

Table 49: Manufacturer Sales by DLC Designation: Overall for Exterior Fixtures 74

Table 50: Manufacturer Sales by DLC Designation by Product Category..... 74

Table 51: Number of Manufacturer Reps Surveyed that Sell each Product Category 76

Table 52: Manufacturer Rep Sales by Technology 76

Table 53: Manufacturer Rep Sales by Technology, by Product Category 77

Table 54: Manufacturer Rep Responses to DLC Listing for New Construction and Retrofit Projects77

Table 55: Manufacturer Rep DLC designation by Product Category 78

Table 56: Manufacturer Rep Projections of LED Penetration 79

Table 57: Manufacturer Rep Responses to Technologies Retrofitted, by Product Category 80

Table 58: Number of Maintenance Contractors Surveyed that Maintain each Product Category 81

Table 59: Percent of Contractor Fixture Installations that are New Construction, Retrofits, and Replacements 82

Table 60: Maintenance Contractor Responses to Percent of Installations that are Replacements83

Table 61: Maintenance Contractors Installations by Technology 84

Table 62: Maintenance Contractor Installations by DLC Designation..... 84

Table 63: Maintenance Contractor Projections of Penetrations of LEDs..... 85

Table 64: Estimates of Sales by DLC Designation for Each Product Category 86

Table 65: Efficacy Results by DLC Designation: Streetlight and Pole Mount..... 89

Table 66: Efficacy Results by DLC Designation: Wall Mount and Floodlight 90

Table 67: Efficacy Results by DLC Designation: Bollard and Fuel Canopy 90

Table 68: Efficacy Results by DLC Designation: Parking Garage 91

Table 69: Price Projections for 2019 91

Table 70: Price Projections for 2020 92

Table 71: Price Projections for 2021 92

Table 72: Price Projections for 2022 92

Table 73: Price Projections for 2023 92

Table 74: LED Efficacy Projections for 2019 100

Table 75: LED Efficacy Projections for 2020 100

Table 76: LED Efficacy Projections for 2021 100

Table 77: LED Efficacy Projections for 2022 101

Table 78: LED Efficacy Projections for 2023 101

I. EXECUTIVE SUMMARY

On behalf of the California electric Investor Owned Utilities (IOUs) and led by Southern California Edison (SCE), TRC conducted a Standard Practice Baseline and Workpaper Support study for Nonresidential Exterior Lighting Fixtures and Retrofit Kits. The primary purpose is to provide workpaper inputs for exterior lighting fixtures, in response to California Public Utilities Commission (CPUC) dispositions.

As an overview of data collection approaches, TRC:

- ◆ Conducted 28 surveys with three types of market actors: six manufacturers, eleven manufacturer representatives, and eleven maintenance contractors to gather their estimates of sales by technology, sales by DesignLights Consortium (DLC) designation (i.e., fraction that are DLC Premium, DLC Standard, and Non-DLC listed), their estimates of their LED penetration for future sales, barriers to retrofits, and estimates of technologies removed in retrofits. TRC estimates our survey responses represent at least half of the California exterior lighting market, since we surveyed three of the five major exterior lighting manufacturers, and our manufacturer rep and contractor surveys broadened our market representation.
- ◆ Collected product pricing and efficacy data for almost 800 LED fixtures using quotes from manufacturer reps and on-line product information and weighted this availability data based on market actors' responses to their fraction of exterior fixture sales and installations by DLC designation.
- ◆ Compared our standard practice efficacy results with products in Title 24-2019 analysis.
- ◆ Reviewed past studies, including projections of LED efficacy and pricing for fixture sales through 2023.
- ◆ Leveraged and expanded TRC's model of installed fixtures to provide an estimate of *installed* fixtures by technology through 2023, and validated this model using market actor survey responses and published studies of installed stock.

The following is a summary of results.

I.1 Standard Practice for Exterior Lighting Sales and Projections

To align with CPUC definitions, this report uses "standard practice" to refer to the market's current practices for exterior lighting sales, in terms of penetration by technology, efficacy, and pricing, for new construction and retrofits (including renovations) in California. Exterior lighting sales for maintenance (i.e., replacement of only failed lamps, ballasts, or fixtures) is not included in this definition of standard practice.

LEDs dominate current exterior fixture sales in California. All market actors surveyed reported that LEDs comprise the majority of their exterior lighting fixture sales and installations in new construction and retrofit projects. **TRC's best point estimate is that LEDs comprise 94% of current exterior fixture sales.** TRC found almost no difference in LED penetration between new construction and retrofits, generally no difference in LED penetrations for retrofits and new construction projects among customer types¹, and generally little difference in LED penetration among the product categories. According to Resolution E4952, CPUC will assume 100% LEDs

¹ Market actors reported that almost all commercial customer types will choose LEDs for a new construction or retrofit exterior lighting project. It was beyond the scope of this project to explore whether certain customer types are more likely choose to pursue a retrofit or maintain their existing system.

for all exterior lighting categories beginning January 1, 2019². For the product categories in this study, our findings indicate this is a reasonable assumption.

Market actors surveyed predicted that by 2020 and 2023, LEDs will comprise 98% and 99% of their exterior sales for retrofits and new construction, respectively. These findings are significantly higher penetrations of LEDs than what DOE predicted nationally: 75% penetration of LEDs for outdoor lighting sales by 2020 and 97% by 2025 (DOE 2014). The discrepancy may be due to differences between California and the rest of the U.S. due to code, utility programs, or customer business practices; because we collected data more recently than DOE; due to differences in methodology; or for other reasons.

Based on the average weighted response across market actors, **DLC Standard fixtures are the most prevalent among current exterior fixture sales and installations**, followed by DLC Premium, and finally non-DLC listed. While there was some difference in the percentage splits by product category, all product categories followed this overall trend. **TRC's best point estimate is 58% DLC Standard, 31% DLC Premium, and 10% not DLC listed across all exterior LED fixtures³.** All types of market actors reported that DLC-listed fixtures (either DLC Premium or DLC Standard) are at least 85% of exterior fixture sales, but there was less consistency in the split between DLC Premium and DLC Standard among market actors.

TRC collected efficacy and pricing data for a range of products using pricing quotes from manufacturer reps and information from on-line retailers. The data includes non-DLC, DLC Standard, and DLC Premium fixtures. While there was considerable variation in efficacy for many non-DLC listed products, their average efficacy is lower than the average efficacy for DLC Standard products in the same product category, and the average efficacy for DLC Standard products was lower than for DLC Premium. For each product category, TRC then multiplied the DLC rating percentages by the average efficacy for each DLC designation to estimate standard practice efficacy. TRC used the following equation for each product category:

Standard practice efficacy = 31% x mean efficacy for DLC Premium products + 58% x mean efficacy for DLC Standard products + 10% x mean efficacy for non-DLC listed products.

Results show that standard practice efficacy for almost all product categories is approximately 100 Lumens per Watt or higher, although bollards have lower efficacy. Based on projections for the rate of efficacy increase from DOE, TRC assumed that exterior fixture efficacy will improve by 3.3% annually in the next five years and developed best point estimates for each product category through 2023.

TRC found no consistent trends in pricing, other than the general increase in price with increased lumen output. Prices range considerably within the same group of products and there was no clear trend in pricing based on DLC designation. Lighting equipment has an aesthetic aspect that will influence the pricing (in some cases, very heavily), and the aesthetics of the fixture can influence the efficacy of the fixture as well. TRC used the same approach for LED pricing as efficacy: Within each product category, we multiplied percent DLC-designation (58% DLC Standard, 31% DLC Premium, and 10% non-DLC) by the average price for each DLC designation to develop best point estimates for pricing. Based on published studies, TRC projected prices will decrease 5% to 8% each year. Both current and projected prices have a high level of uncertainty given the large variation in current prices and the disagreement in the literature regarding pricing projections.

² Draft Resolution E4952 <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M225/K049/225049353.PDF>

³ The full values are: 58.4% DLC Standard, 31.4% DLC Premium, and 10.2% non-DLC. TRC used the full values for analysis – including the calculation of standard practice efficacy, but this report shows values rounded to the nearest whole number so as not to imply greater precision than what the study achieved.

1.2 Comparison of Standard Practice to Title 24

TRC found that the standard practice LED efficacy is higher than the Title 24-2019 Codes and Standards Enhancement (CASE) analysis assumptions. TRC compared the standard practice efficacy of pole-mounted, wall-mounted, and fuel canopy fixtures found in our study to Title 24-2019 CASE study efficacy assumptions. For all product categories, standard practice efficacy is higher than the Title 24-2019 efficacy assumptions.

1.3 Installed Exterior Lighting

In addition to investigating the standard practices described above of new fixture sales, TRC developed estimates of the installed stock (existing stock) of exterior lighting. TRC developed a mathematical model to estimate the installed stock of exterior lighting products (fixtures and lamps) from 2001 through 2023 that included Title-24 regulated categories: pole-mounted, wall mounted, flood and spot lighting, bollards, and fuel canopy fixtures. Key assumptions in the model include the following:

- ◆ Measure life of lamps: TRC generally assumed Database of Energy Efficiency Resources (DEER) measure lifetimes for lamp burn outs.
- ◆ Annual rate of exterior lighting retrofits: TRC assumed that exterior lighting fixtures would be retrofitted 3.3% annually (once every 30 years) through 2011, increase to 4% annually for 2012 to 2015 as the market began to adopt LEDs, increase to 5% annually for 2016 to 2020 as LED adoption increased due to falling LED prices, and decline to 4% as LED retrofit opportunities decreased.
- ◆ For each year, TRC assumed that products purchased would reflect standard practices of that time. HID technologies persisted as standard practice for most exterior lighting product categories until 2008, at which time LED adoption began and accelerated with time. For product categories dominated by A-lamp and linear fluorescent lamps, TRC assumed that most purchases were CFL and T8 lamps through the mid-2000s, with LED purchases starting in 2008 and accelerating with time.

As shown in Table 1, HID technologies comprise the largest fraction of the current installed stock (modeled for 2018). **While the model predicts that LEDs are slowly replacing incumbent technologies, HID technologies will dominate electricity use through 2023.** The cumulative electricity use of exterior lighting in the mathematical model is approximately 4 TWh, with HID technologies consuming the majority of electricity. **California’s exterior lighting electricity use could be reduced by approximately one-third – i.e., there is approximately 1.3 TWh of savings available** if the entire 2018 existing stock of exterior lighting was converted to LEDs. Figure 18 and Figure 19 provide graphical presentations of the values shown here and for other years.

Table 1: Estimate of Installed Exterior Lighting Products and their Electricity Use in California in 2018 and 2023

Technology	HID	LED	CFL	Linear Fluorescent
Installed Stock of Lighting Products, 2018 (%)	35%	34%	25%	6%
Installed Stock of Lighting Products, 2023 (%)	26%	58%	11%	5%
Electricity Use of Installed Stock, 2018 (%)	77%	16%	4%	3%
Electricity Use of Installed Stock, 2023 (%)	65%	31%	2%	2%

To validate the model, TRC compared results of our model of installed products with literature and market actor survey responses. Our model results generally align with published studies (data generally collected 2009 to 2017), which show the installed stock of exterior lighting is dominated by HID and fluorescent technologies, and

that LEDs remain the minority (but growing fraction) of installed stock. In addition, TRC used market actor survey responses for one of the key model inputs: the percent of LEDs among retrofit and new construction projects. However, TRC could not find a published value for the fraction of exterior lighting systems that are retrofitted, compared to maintained, each year. Consequently, TRC relied on our professional best judgment to estimate the percent of exterior lighting systems retrofitted each year, with a peak retrofit rate of 5% from 2016 to 2020 due to falling prices of LEDs. Different assumptions for retrofit rates would lead to different penetrations of technology and their electricity use. In addition, future exterior lighting retrofit rates will be affected by the size of IOU programs to support these projects. Overall, TRC estimates that Table 1 percentages are accurate within approximately 15%.

As further validation of our mathematical model, manufacturer reps and maintenance contractors reported that HIDs are retrofitted most often for almost all product categories, which aligns with the findings of our model. Market actors reported that linear fluorescents are frequently retrofitted in fuel canopy and parking garage projects, and CFLs are often retrofitted in wall mounted and bollard applications.

1.4 The Maintenance Market and Barriers to Retrofits

Many data sources indicate that commercial customers choose to maintain their existing exterior lighting system – i.e., replace failed lamps and fixtures, instead of retrofitting the entire system. National Electrical Manufacturer Association (NEMA) lamp indices show that HID lamp sales have dropped significantly but continue to be sold in large quantities. NEMA sales indices show that fluorescent technologies (primarily T8s, followed by T12s and T5s) comprise over 75% of linear lamps, with TLEDs comprising just under 25%. TRC's surveys with manufacturer reps and maintenance contractors also found that many customers choose to maintain the existing system instead of pursuing a retrofit.

Manufacturer reps and maintenance contractors reported that **the primary reason why customers choose to maintain – instead of retrofit – their exterior lighting systems is cost.** These market actors reported that most customers maintain the system with the same technology if possible (i.e., replace like with like). Some of them indicated a need for educating customers so they understand the true financial benefit of an LED retrofit.

1.5 Recommendations

The CPUC should revisit the approach of the incremental measure cost (IMC) calculation for retrofit fixture projects, so it reflects a mix of fixture and lamp replacements to better model a customer's decision. The IMC calculation in current IOU work papers for fixtures assumes that the base case is a standard practice fixture. Based on our findings, a standard practice fixture would be an LED (with an efficacy that depends on the product category and output). However, that IMC calculation does not represent a customer's decisions. The typical choice facing the customer is to maintain the existing system by replacing failed lamps (and possibly ballasts) with the old technology, or to conduct a retrofit with LED fixtures. TRC calculated an example to investigate how the IMC would change if the base case assumed a blend of maintenance (cost for incumbent technology lamp replacements) and retrofits (cost for LED fixtures). For high-output pole-mounted fixtures, a base case that assumes a blend of HID lamps and LED fixtures has an estimated cost of \$145, which would yield an IMC of \$813. The current IMC methodology in work papers assumes that the base measure is a standard practice fixture – found here to be an LED fixture with an average price of \$1,000, which yields a negative IMC: -\$42. The negative IMC is a major reason that IOUs are not incentivizing many exterior lighting product categories. Adjusting the IMC to assume that the base case is a blend of incumbent technology lamps and LED fixtures would better reflect a customer's decision and significantly increase IMC results.

Furthermore, there is an opportunity to incentivize selection of lighting products that exceed both the prototypical code baseline products and the ISP in the case of both retrofit and new construction. Since codes lag behind the technology considerably and current ISP may or may not primarily consist of the best performing products, incentives will encourage adoption of the best performers, even if the cost increment is small.

The CPUC or IOUs should conduct a follow-up study to further explore pricing of exterior LED fixtures, and how these are likely to change in the future. This study found significant variation in pricing among LED fixtures, but it was beyond the scope of this study to identify why certain product types carried higher prices. In addition, the price projections in this study have high uncertainty since even the direction of LED fixture prices (increase or decrease) was uncertain in the literature. TRC recommends that an IMC study explore 1. Current pricing trends, including investigating why some products carry higher prices than others, and 2. The impact of different forces on future pricing, including the declining costs of LED technology, additional costs due to new LED features, and the impacts of tariffs, to provide more accurate pricing projections. **In addition, TRC recommends additional research to determine exterior lighting retrofit rates.**

In conclusion, while TRC found that LEDs are standard practice, TRC recommends that IOU intervention continue for existing exterior lighting projects. IOU incentives and education will help customers overcome the first-cost barrier of performing an LED retrofit, rather than choosing to maintain the existing system by replacing failed lamps with incumbent technologies. This intervention would help accelerate the shift of existing stock from majority HIDs to majority LEDs, generating significant energy savings.

2. INTRODUCTION

2.1 Overview and Purpose

On behalf of the California electric Investor Owned Utilities (IOUs) and led by Southern California Edison (SCE), TRC conducted a Standard Practice Baseline and Workpaper Support study for Nonresidential Exterior Lighting Fixtures and Retrofit Kits. The primary purpose of the study is to provide workpaper inputs for exterior lighting fixtures, including identifying the standard practice baseline for replace-on-burn out (ROB)/ Normal Replacement (NR)/ Code Equivalent (CE)/ 2nd baseline for Early Retirement (ER, all defined below), in response to California Public Utilities Commission (CPUC) dispositions.

2.2 Terminology and Dual Baseline Description

In the CPUC dispositions and throughout this document, the following terms and acronyms are used:

Table 2: Key Terms

Acronym	Term	Description
DEER	Database for Energy Efficiency Resources	Source of deemed energy savings values.
EUL	Effective Useful Life	The estimated median number of years that the measures installed under the program are still in place and operable.
ISP	Industry Standard Practice	Typical practices for the purchase of new equipment: in this case, new exterior fixtures for new construction and retrofit projects.
RUL	Remaining Useful Life	Estimated number of years that a measure would remain in place and operate.
Replacement and Installation Categories		
AR	Accelerated Replacement	Replacement of a measure before its remaining useful life expired. AR includes three sub-categories: repair eligible, repair indefinitely, and early retirement (ER), where each is subject to a standard dual baseline approach ⁴ .
CE	Code Equivalent	The performance level of lighting fixtures that are equivalent to those used to meet current code (Title-24 2016) ⁵ .
ER	Early Retirement	Replacement of existing equipment (that would have remained in operation for at least the remaining life of the existing equipment), due to program influence.
NC	New Construction	Installation of a measure for newly constructed buildings or additions.
NR	Normal Replacement	Replacement of a measure that is still functional but where evidence does not support a determination of program-induced early retirement.
ROB	Replace on Burnout	Replacement of a measure that it is no longer operable.
Fixture Light Source Technologies		
HID		High Intensity Discharge. A group of technologies that includes MH, HPS, LPS, and MV.
HPS		High pressure sodium
LPS		Low pressure sodium
MH		Metal halide
MV		Mercury vapor

⁴ CPUC, D.16-08-019, Resolution E-4818

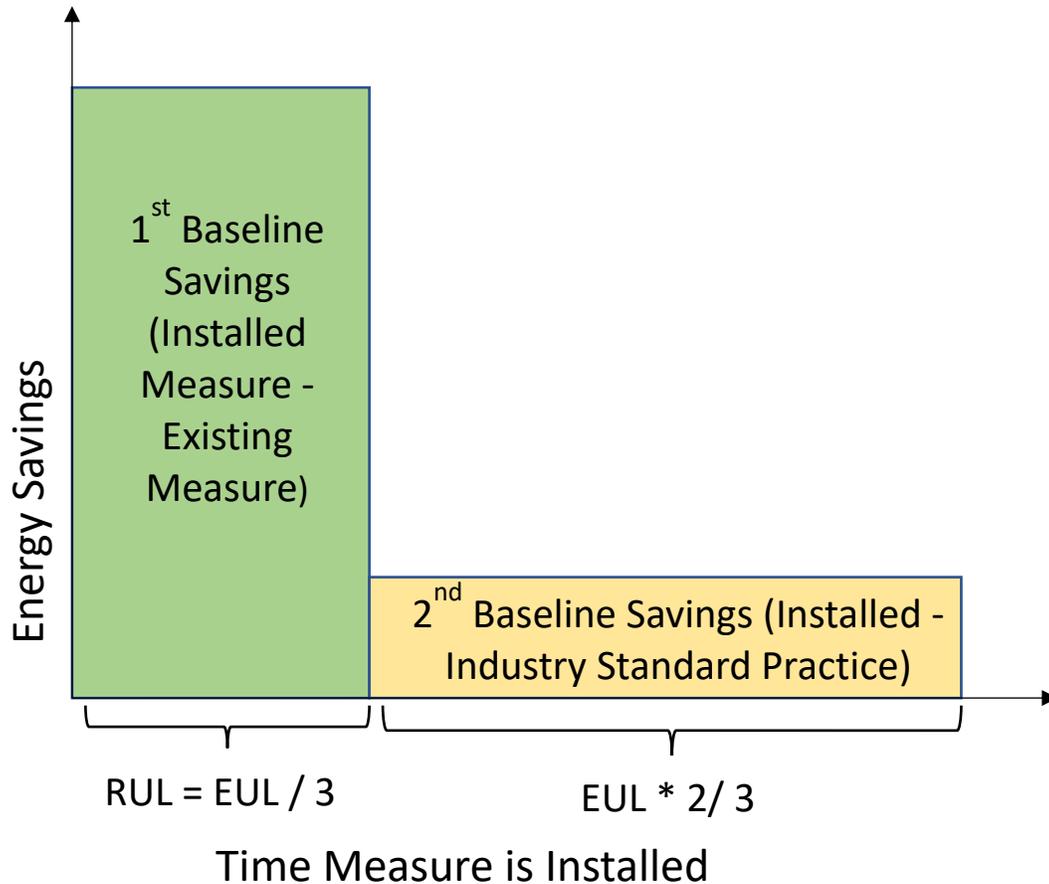
⁵ Because Title 24 uses lighting power allowance (LPA) requirements rather than efficacy requirements, TRC reviewed the efficacy of fixtures used in the Title 24-2019 analysis.

As described above, AR includes three subcategories:

1. **Repair Eligible:** refers to a measure such as shell or envelope equipment, such as windows or insulation, which do not burn out over time.
2. **Repair Indefinitely:** refers to equipment such as a boiler, which could be repaired or overhauled indefinitely until it is no longer feasible or cost-effective.
3. **Early Retirement:** refers to replacement of existing equipment (that would have remained in operation for at least the remaining life of the existing equipment), due to program influence. This is the case for many exterior lighting fixtures.

TRC believes that ER is the primary sub-category of AR that applies to exterior lighting fixtures. Figure 1 illustrates the “dual baseline” method of calculating lifetime energy savings from ER measures. The first baseline is the replaced (existing) measure, and the second baseline is the standard practice for purchased fixtures. The dual baseline calculation assumes that the first baseline (the existing measure) lasts for one-third of the effective useful life (EUL) of the existing measure, and the standard practice baseline lasts for the remaining two-thirds of the EUL. As shown in Figure 1, for a program measure installed through ER, there are higher annual savings under the first baseline, if the existing (incumbent) measure had a high energy consumption. Under the second baseline, annual energy savings drops because the energy consumption for industry standard practice is lower than for existing equipment.

Figure 1: Illustration of Lifetime Savings Calculation for ER Measures Using a Dual Baseline⁶



Note that Figure 1 only illustrates savings for ER measures. For normal replacement (NR), replace-on-burn out (ROB), or new construction (NC), energy savings are calculated as installed wattage minus industry standard practice – i.e., savings are calculated as shown above for the 2nd baseline of ER.

2.3 Background – Summary of Related CPUC Dispositions

The CPUC has addressed exterior lighting as part of several dispositions, as well as Final Resolution E 4867 for DEER Updates⁷. Highlights of the CPUC dispositions (in chronological order) include:

- ◆ 3/1/17⁸: **“The DEER 2018 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.”**

⁶ TRC developed this figure, based on a diagram from MacCurdy et al., “Dual Baselines for Industrial Retrofits that Trigger Energy Codes”, ACEEE Summer Study 2013.

⁷ docs.cpuc.ca.gov/PublishedDocs/Published/G000/M194/K747/194747856.PDF

⁸ “Disposition for workpapers covering exterior LED lighting fixtures”, 3/1/17.

- ◆ 3/1/18⁹: “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:**

- a. Streetlights: 100% LED,
- b. Roadway / Area: 100% LED,
- c. Garage: Proposed workpaper baseline is acceptable [20% metal halide, 20% linear fluorescent, 60% LED],
- d. Wall-mounted: 100% LED,
- e. Canopy: 100% LED”

For exterior lighting projects, the PAs (or SCE individually) shall, within two weeks of the date of the posting of this EAR¹⁰ document, enumerate the situations where ISP is likely an LED technology and thus significantly different from current code or regulation requirements. After the preliminary enumeration, the PAs (or SCE individually) shall proceed **to immediately work collaboratively with CS¹¹ 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/ CE and the second period baseline for ER.**”

- ◆ 5/7/2018¹²:” The workpaper uses a fixed baseline mixture of technologies and performance across all measures within a fixture class (streetlight, roadway/area, canopy, garage and wall mount). This baseline may not be appropriate for all customer classes. Furthermore, some customer classes may offer an opportunity under an accelerated replacement (AR) measure application. As also discussed in the Phase 1 disposition, the current workpaper revision only covers NR (or ROB) and NC measure applications. For accelerated replacement (which may also be appropriate treatment for “one off” fixture replacements, or certain customer classes) it is appropriate to add that measure type treatment in a future workpaper submission. Such a submission would need to include the preponderance of evidence (PoE) approach that would be used to establish program induced accelerated replacements to qualify the participant for the AR treatment. The standard practice baseline assignments approved on an interim basis are also appropriate for use as the second baseline in a AR measure application. The results of the baseline study, upon CPUC staff review and approval, should also be considered in any update to the AR second baseline.”
- ◆ 10/11/18¹³: “In addition to incorporating measures covered by recent workpaper dispositions, **DEER2019 updates the standard practice baseline for all other NR, NC, ROB and AR measures to be based on LED technologies ... the code/ standard practice baseline for hardwired fixtures that were not previously covered by 2018 Phase 1 dispositions shall be 100 lumens per watt.** This level shall apply to all measure application types including accelerated replacement, normal replacement and new construction starting January 1, 2019.”

⁹ CPUC, March 1, 2018: 2018 Outdoor Lighting Phase I Disposition

¹⁰ Ex Ante Review

¹¹ Commission Staff

¹² CPUC, May 7, 2018: 2018 Outdoor Lighting Disposition Update Covering Workpaper Resubmission in Response to A 2018 Phase 1 Disposition

¹³ Draft Resolutions E4952 <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M225/K049/225049353.PDF>

2.4 Research Questions

Based on a review of the dispositions and comments from the IOUs, TRC developed the following research questions for this study, shown in Table 3.

Table 3: Research Questions

Research Questions	Purpose	Include 5-Year Projection
<p>1. ♦ For instances in which working fixtures with RUL are being replaced, what is the approximate fraction of exterior lighting fixtures being replaced, by technology, for each product category in the past twelve months?</p> <p>♦ For each product category, what is the projected trend for each of the next five years by technology?</p> <p>♦ Are there differences in practices for small and medium business customers compared with large business customers?</p>	<p>Support development of a revised first baseline for ER (also called pre-existing baseline)</p>	<p>Yes</p>
<p>2. ♦ What is the approximate fraction of exterior lighting fixtures sold by technology, for each product category, in the past twelve months?</p> <p>♦ For each product category, what are the projected sales trends for each of the next five years for exterior lighting fixtures, by technology?</p> <p>♦ Although TRC agrees with CPUC’s recent disposition that LEDs are likely to be the baseline for many exterior lighting product categories, this study will investigate: are there any specific product exterior lighting categories where a significant (≥10%) fraction of sales are not LED?</p> <p>♦ Are there differences in practices for small and medium business customers compared with large business customers?</p> <p>♦ Are there differences in practices by customer segment (e.g., offices, schools, retail, etc.)?</p>	<p>Support development of a revised ROB / NR baseline</p>	<p>Yes</p>
<p>3. ♦ For the exterior lighting fixtures sold in the past twelve months, by technology and product category, what are the estimated lumens per Watt? Because efficacy can vary significantly among different LEDs for the same product category, of those that are LED, approximately what fraction are DLC Premium, DLC Standard, and non-DLC, and what is the efficacy (range, and some indicator of typical efficacy) for each product group?</p> <p>♦ What is the projected efficacy for fixtures to be sold in the next five years?</p> <p>♦ For the exterior lighting fixtures being replaced in the past twelve months, what are the average (or range of) lumens per Watt by technology for each product category?</p> <p>♦ For fixtures sold and fixtures being replaced, what is the projected trend in change of lumens per Watt for each of the next five years?</p>	<p>Support development of measure structures and savings</p>	<p>Yes</p>
<p>4. ♦ For exterior lighting fixtures sold in the past twelve months, by technology and product category, what is the cost of those fixtures? Note that this project will not be a full incremental cost study.</p> <p>♦ What is the projected trend for each of the next five years?</p> <p>♦ What happens to the LED market (product pricing, availability, market share, and LED performance) over this time, and what will this do to baseline costs and efficacy?</p>	<p>Support development of base and measure case costs</p>	<p>Yes</p>
<p>5. ♦ How do code requirements for efficacy compare with ISP efficacy?</p>	<p>Respond to disposition question of whether ISP is higher than code</p>	<p>No</p>

Note that:

- ◆ While this project collected data on differences by customer types, it was beyond the scope to conduct a full customer segmentation study.
- ◆ While this project collected some pricing data, this was not a full incremental measure cost study.

2.5 Product Categories for Investigation

The product categories for exterior lighting fixtures that this study investigated were as follows:

1. Streetlight
2. Pole Mount, including parking lot and pedestrian fixtures
3. Wall Mount fixtures
4. Floodlight, (including spotlights)
5. Bollard
6. Fuel Canopy
7. Parking Garage

The IOUs had initially requested that TRC also gather data for pool lighting and street sign lighting, but later removed these from the project scope. Consequently, TRC collected limited data for these categories¹⁴. This report presents that data, but since there is not enough to determine standard practices, pool lighting and street sign lighting are not included in the study conclusions.

Note that Title 24 regulates commercial and residential pole-mount, wall mount, floodlight, bollard, and fuel canopy fixtures as “outdoor lighting”. Under Title 24, parking garage lighting is considered indoor (unconditioned) lighting, and Title 24 does not regulate pool lighting, streetlighting, or street sign lighting.

2.6 Structure of Report

This report is organized as follows:

- ◆ **Introduction:** Provides the background for the study, introduces key terms, and the research questions.
- ◆ **Methodology:** Describes the data collection and analysis methods. Section 7.1 in the appendix provides additional detail for TRC’s methodology of identifying market actors for surveys.
- ◆ **Analysis and Results:** Provides results, organized by topic. For example, Section 4.1 provides our estimates of the current mix of exterior fixture sales by technology, and projected penetrations of LEDs, based on all market actor surveys and the literature review. The appendix provides additional results organized by data collection method, including additional results of market actor surveys, and supporting data identified in our literature review.
- ◆ **Conclusions:** Summarizes main findings from the study and provides recommendations based on results.
- ◆ **References:** Lists studies referenced in this report and provides links to those studies.
- ◆ **Appendix:** Provides additional detail on TRC’s methodology for identifying market actors for surveys, detailed results from market actor surveys, additional analysis of efficacy and pricing data, additional results from our literature review, and the market actor survey guide.

¹⁴ TRC asked market actors in surveys for data on pool lighting and street sign lighting, although most market actors surveyed did not sell or install them. In addition, TRC collected pricing and efficacy information for a few pool lighting and street sign lighting products. To determine standard practices for these categories, a researcher would need to survey market actors that specifically target these products and collect efficacy and pricing information for products that are comparable to those the IOUs would incentivize.

3. METHODOLOGY

This section begins with an overview of data collection activities and how they map to the research questions, and then provides a subsection with more detail on each of these data collection activity.

3.1 Overview of Data Collection

As an overview of data collection approaches, TRC:

- ◆ Conducted surveys with three types of market actors: manufacturers, manufacturer representatives – i.e., independent entities that sell products from one or more manufacturers to lighting distributors or directly to customers, and maintenance contractors to gather their estimates of sales by technology, sales by DLC designation (i.e., fraction that are DLC Premium, DLC Standard, and non-DLC listed), their estimates of their LED penetration for future sales, barriers to retrofits, and estimates of technologies removed in retrofits.
- ◆ Collected product pricing and efficacy data using quotes from manufacturer reps and on-line product information to identify current standard practice; and used projected rates of change for LED efficacy and pricing from published studies to estimate future efficacy and pricing
- ◆ Identified efficacy and pricing for products in Title 24-2019 analysis.
- ◆ Leveraged and expanded TRC’s model of installed fixtures to provide an estimate of *installed* exterior lighting products by technology through 2023 and compared these with literature results.

Note that this study collected data from manufacturer reps in two separate efforts to collect different information. TRC conducted phone surveys with manufacturer reps regarding standard practices for sales. TRC’s subcontractor requested product information from manufacturer reps for product efficacy and pricing information. Because these efforts collected different information, and to reduce the burden of individual manufacturer reps, the study team did not coordinate these efforts and contacted different manufacturer reps.

Table 4 on the next page provides an overview of how each data collection effort addressed one or multiple study research question(s).

Table 4: Data Collection Activities Mapped to Research Questions

Data Collection Efforts	Q1: Fixtures Replaced, by Technology	Q2: Fixtures Sold by Technology, and DLC designation	Q3: Efficacy of Fixtures Sold	Q4: Price of Fixtures Sold	Q5: Efficacy for Fixtures Sold vs. Code Efficacy
Surveyed 11 manufacturer reps.	✓	✓			
Surveyed 6 manufacturers.		✓			
Surveyed 11 maintenance contractors.	✓	✓			
Collected LED efficacy and pricing for almost 800 products using manufacturer reps’ price quotes and cross-referenced products ¹⁵ , and by collecting data from two major on-line retailers for commercial lighting fixtures.			✓	✓	✓
Collected Title 24-2019 analysis, including product efficacy assumptions.					✓
Purchased market research reports that include projections of LED pricing.				✓ (for price projection)	
Projected TRC’s lamp and fixture replacement model to 2023 and compared results to past studies of installed fixtures, and market actor responses of technologies replaced.	✓				

3.2 Market Actor Survey Methodology

Because commercial lighting sales data is not available, TRC used surveys with market actors to identify standard practices for lighting sales by technology, DLC designation, and to answer other research questions.

3.2.1 Lighting Market Actor Contact Identification

TRC used a combination of internet searches –the main source of contacts for manufacturer reps and maintenance contractors, and TRC and IOU personal contacts – the main source of contacts for manufacturers – to develop a population of contacts. TRC identified contacts from each electric IOU territory for statewide representation, and focused on market actors with larger sales volumes such as larger manufacturers – based on our industry knowledge – and their manufacturer reps. Section 7.1 in the Appendix provides more detail on our method for identifying contacts.

3.2.2 Recruitment

To recruit a market actor for a survey, TRC first sent an email that briefly described the purpose of the survey, gave an overview of the survey questions, and offered a \$50 gift card for survey completion. The email requested that the recipient contact TRC to schedule a time for the survey or refer us to a colleague if that

¹⁵ A manufacturer rep will “cross-reference” a product by receiving a price quote for one product (for a specific manufacturer) and providing a price quote for that product, as well as prices for similar products from other manufacturers that are considered functionally and aesthetically comparable.

person could better provide the requested information. After two to three business days, if there was no response to the email, TRC followed up with respondents by phone. The manufacturer and manufacturer rep surveys were 25 to 30 minutes. Because maintenance contractors were the hardest to reach and almost always declined due to time constraints, TRC shortened their survey guide to 20 minutes. To cut the survey length, TRC did not ask maintenance contractors for differences in practice between new construction and retrofits, nor for differences in sales by technology by product category, because our manufacturer and manufacturer reps survey suggested that these differences were none to very small. The following notes provide more detail for each type of market actor:

- ◆ TRC provided non-disclosure agreements prior to the survey for manufacturers when requested.
- ◆ Many manufacturer rep companies have multiple reps in one office that serve the same region. So as not to over-represent any company office, TRC completed a survey with only one manufacturer rep per region per company.
- ◆ For most maintenance contractors, TRC did not have contact names, and, therefore, did not have email addresses. Consequently, TRC called the main number of the maintenance contractor company without sending an email first, briefly described the survey request, and asked for the best person in the office that could respond to the survey questions.

3.2.3 Survey Dispositions

Table 5 shows the survey dispositions. TRC obtained the target number of surveys for manufacturers and manufacturer reps but completed fewer than the targeted surveys for maintenance contractors. TRC contacted all contractors identified; the majority declined the request, almost all citing lack of time.

Table 5: Survey Dispositions by Respondent Type

	Manufacturer	Manufacturer Reps	Maintenance Contractors
Number of contacts	33	85	97
Number contacted	22	56	97
Targeted	6-7	10-12	15-20
Number completed surveys	6	11	11

In total, TRC completed 28 surveys. TRC believes these market actors were a good representation of the California market since they included market actors from each electric-IOU region and were a mix of IOU-referrals (for which their business practices may be influenced by utility rebates) and cold-calls (that would be less likely to be influenced by utility rebates). Table 6 shows the number of contacts that serve by contact type for each IOU: Southern California Edison (SCE), Pacific Gas and Electric (PG&E), and San Diego Gas and Electric (SDG&E). This figure does not include manufacturers, since they are national or serve a region of the U.S.

Table 6: Manufacturer Rep and Contractor Surveys by IOU Territory

SCE	Manufacturer Reps	5
	Maintenance Contractors	3
	Total	8
PG&E	Manufacturer Reps	3
	Maintenance Contractors	6
	Total	9
SDG&E	Manufacturer Reps	3
	Maintenance Contractors	4
	Total	7

In addition, for four of the five major exterior lighting manufacturers—GE (Current, for their exterior sales line), Acuity, Cooper (Eaton for their exterior sales line), Hubbell, and Philips—TRC completed a survey with either the manufacturer or a manufacturer rep that sells those company’s products, or both.¹⁶ Consequently, TRC was able to get good representation of market actors that serve the major manufacturers’ products.

TRC estimates that our responses reflect at least half of California exterior fixture sales, since TRC was able to interview representatives from three of the five major manufacturers; our interviews with manufacturer reps and maintenance contractors (who sell and install products from a variety of manufacturers) had some overlap of these products, but further extended our reach.

3.2.4 Survey Guide

TRC provides the survey guide for each market actor in the appendix in Section 7.9. At a high level, the surveys had the following sections, where all sales/installations¹⁷ refer to the respondent’s estimate of their office’s exterior fixture sales/installations in California. TRC did not ask manufacturers questions in sections with an asterisk (*), because they are too far removed from the final project to provide informed responses for these questions.

- ◆ **Introduction:** Surveyor described the goal of the study, purpose of the survey, and gathered information about the survey respondent, including their name and role.
- ◆ **Product Categories Served:** Respondent identified which of the product categories s/he sold or installed.
- ◆ **Estimate of Sales/Installations for new construction vs. retrofits*:** Respondent estimated their fixture sales/installations for new construction vs. retrofit projects.
- ◆ **Sales/Installations by Technology:** Respondent estimated percent of sales/installations by technology as an overall value for all exterior fixtures, and for each product category. Respondent also identified differences for new construction vs. retrofit projects and by customer type (e.g., retail, office, restaurant, etc.)
- ◆ **LED DLC/Efficacy:** Respondent estimated fraction of sales/installations by DLC designation (% DLC Premium, % DLC Standard, and % non-DLC) as an overall value for all exterior fixtures, and by product category. Manufacturer respondents and a few manufacturer rep respondents also estimated the typical efficacy – or range of typical efficacies – for each product category.
- ◆ **Projections:** Respondent provided their best estimate for their fraction of exterior lighting sales/installations that would be LEDs in two and five years and commented on whether that might vary by product category.
- ◆ **Fixtures Replaced in Retrofits*:** Respondent provided their estimate of fixtures *removed* in a retrofit project, as a percent by technology, by product category.
- ◆ **Barriers to Retrofits and the Lamp Replacement Market*:** Respondent commented on barriers to retrofits – i.e., why customers are likely to continue to maintain the existing system by replacing only

¹⁶ For the one manufacturer that was not represented, the manufacturer staff member declined the survey request, citing a lack of time. The main manufacturer rep company selling this manufacturer’s products stated it was against their company policy to provide sales information.

¹⁷ The surveyor asked manufacturers and manufacturer reps to provide sales estimates, and maintenance contractors to provide installation estimates.

failed lighting products instead of retrofitting the exterior lighting system. Respondents also commented on what technology is generally installed in maintenance (replacement) projects.

- ◆ **Sales Volume:** Respondent provided a multiple-choice response regarding their company office’s volume of exterior lighting sales/ installations in the past year.

It would have taken considerable time for respondents to analyze their data to provide exact numbers, and TRC doubted that the respondents would invest this effort without a very large incentive. Consequently, TRC asked respondents to provide estimates based on their best professional judgment. Most respondents could confidently provide responses and provided consistent responses throughout the survey. For example, a respondent’s response to the question of overall fixture sales by technology generally aligned with their break-outs of sales by technology by product category.¹⁸ However, several maintenance contractors and a few manufacturer reps reported they could not reliably estimate sales by DLC designation – particularly to split out DLC Premium from DLC Standard products. Consequently, TRC removed several manufacturer rep and maintenance contractor responses for the analysis of sales/installations by DLC designation. Two manufacturers used their databases to provide percentages based on actual sales; as described in the next section, TRC weighted their results the highest when combining survey responses across market actors, because we viewed these to be the most accurate.

3.2.5 Weights for Survey Results

Because some market actors sell or install a larger number of products than others, TRC assigned a weight to each market actor’s response based on their self-reported sales volume and applied that weight when developing a weighted average for each value. This section provides more detail on the weighting methodology.

To develop the weights, TRC asked respondents at the end of the survey to provide a multiple-choice answer to the question of how many exterior lighting fixtures their company office sells (manufacturers and manufacturer reps) or installs (maintenance contractors) in California. A few respondents declined to respond to this question, so TRC used our industry knowledge for the manufacturers, and the company website for the manufacturer reps and maintenance contractors, to estimate market size for each respondent. For manufacturers, two respondents analyzed their data to provide estimates (both at the national level), so TRC weighted these responses the highest, since all other manufacturers responded using their best professional judgment.

The following tables show TRC’s weights for manufacturers, manufacturer reps, and maintenance contractors.

Table 7: Manufacturer Weights

Manufacturer Size and Data Accuracy	Weight	Number of Respondents
Small	1	1
Small/medium	2	1
Medium	3	1
Large, and estimated values based on judgment (not databases)	4	1
Large, and estimated values from company databases	5	2

¹⁸ One manufacturer rep provided inconsistent responses on the technology question, so TRC removed her responses in our analysis of this question.

Table 8: Manufacture Rep Weights

Manufacturer Rep Reported Number of Annual Sales	Weight	Number of Respondents
<50,000	1	4
50,000-100,000	2	2
100,000-150,000	3	0
150,000-200,000	4	1
>200,000	5	4

Table 9: Maintenance Contractor Weights

Maintenance Contractor Reported Number of Annual Installations	Weight	Number of Respondents
<10,000	1	6
10,000-50,000	3	3
>50,000	5	2

TRC used the weighted average as our final values, but we present the simple average (calculated by assuming equal weights for all market actors of the same type) for comparison. **As described in more detail in Section 4, most market actors provided similar results, so the weighted responses to most questions do not vary significantly from the simple average.**

For many questions, TRC combined responses across market actors to produce one weighted average. TRC assumed the weights for each group of market actors shown in Table 10. These weights reflect the pyramid structure of lighting sales, where there are a relatively small number of manufacturers (<100) selling exterior lighting products in California, a larger number of manufacturer reps (a few hundred) selling these products, and an even larger number of maintenance contractors (several hundred) installing these products.

Table 10: Weights across Market Actors

Market Actor	Weights
Manufacturers	4
Manufacturer Reps	2
Maintenance Contractors	1

Similar to the weights *within* each market actor group, responses *among* the different market actor groups were generally similar. Consequently, the weighted responses were generally similar to results calculated using a simple weighted average among market actors. The one difference was for the response of percentages of sales by DLC designation: All market actor groups reported that the vast majority of sales are DLC, but manufacturer reps and contractors reported a higher fraction of DLC Premium products compared to what manufacturers reported. Section 4.2.3 provides results to that question and describes TRC’s methodology for estimating sales by DLC designation.

3.3 Pricing and Efficacy Data Collection

To collect product pricing and efficacy, the study team (TRC and a subcontractor¹⁹ that provides lighting design services) used two methods:

1. Identified representative products for each product category by reviewing products available and using professional judgment, including the subcontractor's experience with exterior lighting projects, to select representative LED fixtures. The study team provided these products to manufacturer reps to request pricing information and asked them to identify similar products from other manufacturers (a.k.a., "cross-reference") and provide pricing and efficacy for these comparable products.
2. Collected product information available online from suppliers' websites to further expand our catalogue of LED product pricing and efficacy.

The first strategy represents the more traditional specification method for commercial products, and TRC used the second method to augment the data set. The following subsections provides detail for each method.

3.3.1 Data from Manufacturers Reps

For each of product category in the study, TRC reviewed the range of product types available within the commercial specification-grade market. TRC limited searches to products sold via the typical commercial methods involving sales agencies and distribution chains to best align the overall effort with typical products used for both new construction and retrofit applications.

Within each product category, TRC identified individual products that provide a sampling of the range of product possibilities, including:

- ◆ Physical quality of product
- ◆ Aesthetics
- ◆ Reputation of manufacturer
- ◆ Efficacy
- ◆ Range of power options available
- ◆ Range of efficacies available
- ◆ Range of optics available
- ◆ DLC designation status (not listed, standard, premium)

TRC specified all products with a 3000K correlated color temperature (CCT) where possible to align with best practices to reduce light pollution by minimizing short wavelength energy. In the few cases where a 3000K CCT was not a standard option, the maximum color temperature specified was 4000K.

Additionally, TRC targeted optical performance, specifically backlight uplight and glare (BUG) Ratings, that generally aligned with compliance with Lighting Zones 2 (suburban) and 3 (urban) per CalGreen requirements (Title 24 Part 11). Specific to area lighting, TRC selected products that are U0-rated (i.e. meet full cutoff requirements). Within each product category where a range of standard optical distributions are offered, TRC chose typical product distributions for all products within that category to avoid conflating natural variations in efficacy due to variations in optical distribution with inherent fixture efficacy.

¹⁹ This subcontractor preferred to remain anonymous, because – to collect the most accurate information – they did not identify in price quote requests that the information would be used for a research project.

Finally, TRC specifically targeted products that offer the ability to incorporate a range of light output and wattage from a single fixture configuration, typically achieved by varying the drive current of the LED driver. This allowed TRC to further examine the range of efficacy achievable within each specific product configuration, providing a wider breadth of product configurations for analysis. In addition, this helps represent what has been identified as the current trend in the product market toward standardizing product offerings to minimize manufacturing complexity.

TRC also avoided products that included built-in controls capabilities. This is an emerging aspect of the LED lighting market, and the added costs of integrated controls will obfuscate the real costs of lighting equipment in for a given light output. Currently, most lighting fixtures are available without integrated controls, but presumably this is an expanding market, and in time it may become more difficult to purchase lighting products that do not include integrated controls.

Based on the preliminary fixture selection, TRC's subcontractor contacted local sales agencies in California and requested pricing for the specified products. TRC also asked sales agents to cross-reference the specified products with additional products they represent to further expand the number of products included in the assessment. Table 11 summarizes the number of products configurations reviewed for each product category:

Table 11: Number of Products in Manufacturer Rep Data Set for Pricing and Efficacy

Product Category	Quantity of Specified Product Configurations	Quantity of Cross-Reference Product Configurations	Total Product Configurations
Streetlight	112	15	127
Pole Mount	81	36	117
Wall Mount	39	34	73
Floodlight	42	17	59
Bollard	11	9	20
Fuel Canopy	41	9	50
Parking Garage	51	13	64
Swimming Pool	1	1	2
Street Sign	n/a	n/a	n/a
Total	378	134	512

3.3.2 Online Sales Channels

TRC employed a similar approach for collecting products for online sources but made some modifications to selecting products for reasons described below.

Online sources do include some product variety, but the number of manufacturers and the individual products available is less varied than the myriad of choices available through the traditional manufacturers rep and distribution channel. Because of this, TRC was not able to be as selective of the specific product characteristics that we used in the local pricing quotes. For example, TRC included products up to 5000K color temperature when there were few products offered in a product line that lower. Similarly, TRC chose to be less selective regarding the BUG ratings of products and the overall light distribution from the products.

TRC used the following data sources for the online efficacy and pricing information: Grainger[®] and 1000bulbs.com[®], since these are major sources for exterior lighting with broad ranges of products. Since the costs presented in these sources are the distributor or wholesale price, TRC applied a markup of 30% (using industry experience) to more closely capture the retail price or manufacturers' suggested retail price (MSRP).

TRC selected suitable products for the survey, collected a range of product information for each one, including the price and DLC designation, if this was available, and recorded the online pricing for each product. TRC attempted to be selective with product selection to reflect the likely purchase pattern of products due to the rapid improvement of LED technology in the market year-to-year. As a product “ages out” of market viability (due to price and efficacy improvements of more recent products), it becomes less viable and the manufacturer will eventually drop it. When a product that met these conditions was noted, TRC excluded it from the dataset. Table 12 summarizes the number of products configurations reviewed for each product category:

Table 12: Number of Products in Online Data Set of Product Pricing and Efficacy

Product Category	Total Online Products Priced
Streetlight	37
Pole Mount	88
Wall Mount	64
Floodlight	62
Bollard	12
Fuel Canopy	13
Parking Garage	25
Total	276

3.3.3 Pricing Model and DLC verification

Once the product information was compiled, TRC modified the prices to ensure that all the values were comparable. In particular, TRC determined which type of quote the manufacturer rep provided. Some of the manufacturers rep provided quotes as “distributor net” (DN) pricing, which does not include contractor mark-ups, and others provided “budget” pricing. If manufacturer rep supplied DN pricing, TRC assumed a 30% markup for the contractor. Online product pricing is effectively DN pricing, so TRC applied the 30% contractor markup to those prices as well. TRC did not include any deliver or shipping costs in either supply chain because the costs should be comparable for both.

TRC attempted to verify the DLC designation of the products in the full list, but this was not possible in some cases because of the wide variety of possible product catalogue number listings that an individual product may have. In general, TRC found that few of the products collected in both online and local pricing matched the exact catalogue listings in the DLC database. TRC assumed the designation of the family of products when we did not find a specific product number match. TRC applied the DLC designation only if we were able to find the specific family that the product belongs to in the DLC database, which was possible in most cases.

TRC also considered DLC updates when assigning DLC designation. The current listings in the DLC database are for technical specification Version 4.3. Some of the products collected online claimed DLC designation status but the DLC database indicates these products have been de-listed for years as the technical specifications advanced with the improvements in LED technology. TRC classified products as not DLC listed if they do not meet the current DLC specifications.

3.4 Calculation of Standard Practice Efficacy and Pricing

TRC calculated standard practice efficacy and pricing for LEDs using a two-step process.

Step 1: Determined average efficacy and pricing for each product grouping by DLC designation: TRC collected product information on LED efficacy and pricing for a range of LED products in each category using the

manufacture rep specs and product information available on-line, as described in Section 2.3. Within each product category, TRC organized the data according to the DLC classifications as shown in Table 13:

Table 13: DLC Classifications by Output

Classification	Lumens	DLC Standard Requirement	DLC Premium Requirement
Lumens per Watt (Minimum)			
Low Output	250-5,000	90	110
Mid Output	5,000-10,000	95	115
High Output	10,000-30,000	100	120
Very High Output	30,000 and up	100	120

TRC analyzed our product data to identify the minimum, maximum, average, and median efficacy and price for each DLC classification (low, mid, and high output), for each DLC designation (DLC Premium, DLC Standard, and not DLC listed). For example, TRC grouped all pole-mounted medium output products that were DLC Premium and identified the minimum, maximum, average, and median efficacy and pricing for that group. TRC then grouped all pole-mounted medium output products that were DLC Standard and identified the efficacy and pricing statistics for that group and did the same for all pole-mounted products that were not DLC listed. TRC applied this method of grouping to identify the minimum, maximum, average, and median efficacy and pricing for each group of products according to their designation (DLC Premium, DLC Standard, or non-DLC listed).

TRC weighted products based on market actor survey responses for sales by DLC designation to calculate the standard practice efficacy and pricing for each group of products, as described in Step 2.

Step 2: Calculated weighted average based on sales by DLC-designation: As part of our market actor surveys, TRC asked market actors for their percent of sales (for manufacturers and manufacturer reps) and installations (for maintenance contractors) that were DLC Premium vs DLC Standard vs not DLC listed. As shown in Table 24 in Section 4, the results based on the weighted average across all market actors (after rounding) were 31% DLC Premium, 58% DLC Standard, and 10% non-DLC listed. TRC then calculated the standard practice efficacy for each group of products as follows:

Standard practice efficacy = 31% x mean efficacy for DLC Premium products + 58% x mean efficacy for DLC Standard products + 10% x mean efficacy for not DLC listed products.

3.5 Comparison of Efficacy and Code

The California Building Energy Efficiency Standard (Title 24) regulates exterior lighting efficacy by lighting power allowance (LPA) requirements (i.e., lumens per square foot) rather than setting minimum efficacy (lumens per watt) levels. TRC reviewed Title 24-2019 Codes and Standards Enhancement (CASE) analysis to identify the efficacy of products assumed in that analysis. TRC then compared the efficacy of those products with the standard practice efficacy that we calculated, as described in Section 3.4.

3.6 Methodology for Developing Model of Installed Exterior Lighting

To estimate the number of existing exterior lighting (i.e., installed stock) in California by technology from 2001 to 2023, TRC developed a mathematical model.²⁰ TRC used the California Outdoor Lighting Baseline Assessment (2003)²¹ as a starting point for the total quantity and distribution of exterior lighting equipment use for 2001, which included the following product categories: pole-mounted, wall mounted, flood and spot lighting, bollards, and fuel canopies. The California Outdoor Lighting Baseline Assessment did not include the following product categories because they are not regulated as part of Title 24 exterior lighting: streetlighting, parking garages, pool lighting, and street sign lighting; consequently, TRC’s mathematical model excludes these categories. Also, TRC’s model includes both fixtures and lamps, since for many lighting products, customers have the option of replacing burned out lamps with new lamps or new fixtures.

While the California Outdoor Lighting Baseline Assessment study is outdated, it represents the most recent data source based on field measurements of existing exterior lighting equipment in California. TRC made the following updates to estimate the installed exterior lighting stock through 2023:

- 1. Exterior lighting existing stock growth through new construction (NC).** TRC tracked the growth of exterior lighting due to NC and modified the total quantity of equipment based on the NC rate for each year. Since this is tracked based on the square footage of interior space, TRC assumed that there is a static ratio of NC square footage to exterior lighting equipment.
- 2. Increasing rates of retrofit activity as LED prices decrease.** TRC did not find a reliable estimate in published literature for the rate of retrofits for exterior lighting systems. Using our best industry judgment, TRC developed the assumptions described in Table 14.

Table 14: Retrofit Rate Assumptions in Exterior Lighting Replacement Model

Timeframe	Retrofit Assumption (%/year)	Rationale
2002 to 2011	3.3%	Assumes a retrofit every 30 years. This is half the DEER assumption for interior spaces (15 years), but there is much less motivation for retrofitting exterior spaces because they are usually not affected by interior remodels or change in business types. Also, HID fixtures can easily last for 30 years.
2012 to 2015	4%	Exterior retrofit rate increases slightly, as LEDs start to drop in price and increase in efficacy.
2016 to 2020	5%	Exterior retrofit rate peaks because LEDs have dropped significantly in price and increased in efficacy.
2021 to 2023	4%	Exterior retrofit rate drops from its peak, since approximately half of existing stock has been converted to LEDs, so retrofit opportunities decrease.

²⁰ TRC had previously developed this model for Title 20 research that provided results through 2016. For this study, TRC updated it to project it forward to 2023, and verified the model’s 2018 results based on responses from market actor surveys.

²¹ RLW Analytics et al., Prepared for California Energy Commission, “California Outdoor Baseline Study” 2003. <http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-18.PDF>

3. **Light source technology improvements and changes over time.** When new lighting technology is introduced into the market, TRC assumed it is incorporated into the stock through NC and retrofit activity. However, the turnover is not immediate for two reasons. First, combined NC and retrofit activity likely impacts a maximum of approximately 5% of the existing stock (i.e., approximately 95% of existing stock does not change each year – as described in Step 2). Secondly, there is some delay before the market fully accepts the technology. Starting with the 2001 data, TRC modeled a turnover of older technology: MH, HPS, incandescent, T12, and T8 fluorescent and effectively replaced the older technologies with newer technologies as they became available to the market at reasonable adoption rates for the technology. TRC assumed that the retrofit portion had slightly higher installations of advanced technologies because of the programs' impacts on that portion of the activity. In addition, TRC accounted for increased efficacy in LEDs over time.
4. **Replacement-on-burnout of certain lamp types.** Table 15 shows the measure life that TRC assumed for lamps in the replacement model and our assumptions for replacements of these lamps. Light sources that employ an Edison screw-base socket, including A-lamps, can change light source technology with relatively little effort. For lighting products that can be replaced through screw-in products: CFL, and incandescent/halogen, TRC assumed lamp burn out would be replaced primarily with CFLs in the early 2000s (since these were the dominant technology at that time) and LEDs starting in 2010. The rate of LED replacement is modeled low at the beginning and has increased until now; the model assumes that the market replaces incumbent Edison screw-base technologies almost entirely with LEDs today. For HID and linear fluorescent fixtures, TRC assumed that most lamp burn-outs will be replaced with a lamp of the same technology; for retrofits, TRC assumed the customer will replace the lighting products with the dominant technology for that year – including LEDs beginning in 2010. Based on market actor survey responses, TRC assumed that LEDs comprised 94% of retrofit and new construction fixtures in 2018, 98% in 2020, and 99% in 2023, and interpolated values for the years in between. Table 15 summarizes assumed measure life and replacement technologies.

Table 15: Assumed Lamp Life Hours and Replacement Technology in Exterior Lighting Replacement Model

Technology	Assumed Lamp Life (Hrs)	Assumption for Evolution of Lighting Installations per Technology
HID	Not Applicable ²²	Assumed HID lamps were replaced with comparable HID lamps unless they are retrofitted to LED fixtures.
Incandescent/ halogen	1,000 for Incandescent 1,500 for halogen	Assumed lamps would be replaced primarily with CFLs in the early 2000s, and primarily with LEDs starting in 2008. Because multiple burn-outs happen each year in commercial areas (HOU for exterior spaces are typically 4,100 hours), there are multiple opportunities to choose a new lamp. TRC assumed that 20% of halogen and 25% of incandescent lamps were replaced by CFLs in the early 2000’s. This results in an almost complete replacement in six years.
CFL	10,000	Assumed CFL lamps that burned out would be replaced with LEDs starting in 2008 at an escalating rate as the years progress.
Linear fluorescent	24,000 up to 40,000	Assumed T12 lamps were replaced with T8 lamps from 2003 until they are all gone, at a decreasing rate of 16% to 8% per year. The market began to install v.2 T9 lamps starting in 2006, and v.3 T8 lamps in 2009. The adoption rate is 16% per year in the early 2000’s based on the assumed hours of operation and life expectancy of the lamps (about 4,000 hours per year, and 24,000 hrs total). As years progress, the rate decreases because the HOU decrease with new controls and the new lamps have longer life expectancy (up to approximately 40,000 hours currently).
LED	50,000 – 100,000	Assumes LED lamps that burn out were replaced with other LEDs. LED retrofit lamps will have shorter life expectancy than fixtures.

- Adjustments to the Hours of Use (HOU) for lighting systems.** TRC reduced the HOU in later years of the model, in part because of the introduction of code mandated lighting controls beyond the basic photocell that was required back in 2001. These requirements reduce the annual HOU of the exterior lighting system considerably; however, because the changes only affect NC and retrofit activity, it takes time for the impact to be complete in the market.

TRC made changes to the model of existing exterior lighting equipment each year from 2001 to 2023 and calculated a running tally of the equipment quantities and annual energy use. Each year, TRC made a new set of adjustments for construction activity, light source technology changes, burnouts, and HOU to project the model of existing stock of exterior lighting products to 2023.

²² The lamp life is not applicable, because the model assumes that HID lamps are replaced with other HID lamps. The only exception is if the HID lamp is replaced with an LED fixture through a retrofit, and the retrofit rate follows Table 14 assumptions.

3.7 Projections

To project the percent of exterior sales that will be LEDs in the next five years, TRC asked market actors in surveys for their estimates of the fraction of their exterior fixture sales (manufacturers and manufacturer reps) and installations (maintenance contractors) that will be LED in two years (2020) and five years (2023). TRC then interpolated results between current LED penetration and the two-year projection for 2019 projection, and interpolated results between the two-year and five-year projection for the 2021 and 2022 projections.

TRC also reviewed literature for projections of LED penetrations in exterior sales. This literature review identified a national projection from DOE (2014) and Freedonia (2018). Because our data was specific to California, TRC assumed the values provided through our market actor surveys, although Section 4.1.2 shows the national projections for comparison.

To project efficacy and pricing, TRC started with our current estimates of efficacy and price based on our catalogue of products collected from manufacturer reps and online data collection and weighted by DLC-designation based on market actor survey responses. TRC then used a DOE (2014) estimate for the annual rate that outdoor LED fixture efficacy would increase. To predict pricing changes, TRC averaged DOE (2014) and Navigant (2018) estimates for the rate that outdoor LED fixture price would change. Sections 4.3 and 4.4 provide more detail on efficacy and pricing projections, respectively.

4. ANALYSIS AND RESULTS

4.1 Current and Projected Penetration of LEDs

4.1.1 Standard Practice by Technology

TRC estimated percent of fixture sales by technology based on market actor survey responses to the question of their exterior lighting sales (for manufacturers and manufacturer reps) and installations (for maintenance contractors) in California in the past year. Table 16 shows results for each type of market actor, and the weighted average across all market actors. See Methodology subsection 3.2.5 for the weighting methodology; in general, manufacturers had the highest weight and maintenance contractors had the lowest, based on the relative number of fixtures sold or installed by each group of market actors.

Table 16: Market Actor Exterior Fixture Sales by Light Source Technology

	LED	MH	HPS	LPS	Linear FL	CFL	Other
Manufacturers							
Minimum	85%	0%	0%	0%	0%	0%	0%
Maximum	100%	10%	7%	1%	1%	1%	0%
Average	95%	2%	2%	0%	0%	0%	0%
Weighted Average	94%	2%	3%	0%	0%	0%	0%
Manufacturer Reps							
Minimum	68%	0%	0%	0%	0%	0%	0%
Maximum	100%	5%	29%	10%	0%	0%	0%
Average	95%	1%	3%	1%	0%	0%	0%
Weighted Average	95%	2%	2%	1%	0%	0%	0%
Maintenance Contractors							
Minimum	43%	0%	0%	0%	0%	0%	0%
Maximum	100%	40%	21%	5%	5%	0%	0%
Average	86%	9%	4%	0%	0%	0%	0%
Weighted Average	89%	9%	2%	0%	0%	0%	0%
Weighted Average across all Market Actors	94%	3%	3%	0%	0%	0%	0%

Table 16 shows that LEDs comprise the vast majority of exterior fixture sales for NC and retrofits, with the weighted average for each market actor type ranging from 89% LEDs for maintenance contractors to 95% LEDs for manufacturer reps. **TRC's best point estimate is the weighted average across all market actors: 94% LEDs.** Based on the differences in response by market actor type, TRC estimates this value is accurate to within 5%.

TRC also asked manufacturer reps and maintenance contractors whether there was a difference in LED adoption by type of customer (e.g., retail, office, school, etc.). In general, market actors responded that most customers install LEDs in both new construction and retrofit applications, regardless of business type.

Table 17 shows market actor estimates of the percent of their LED sales for each product category. This figure only includes responses for manufacturers and manufacturer reps. For survey time constraints, and because responses from manufacturers and manufacturer reps showed relatively difference among product categories, TRC did not ask maintenance contractors for their estimate of sales for each product category.

Table 17: Market Actor Exterior Fixture Sales of LED Products, for each Product Category

	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Street Sign
Manufacturers								
Minimum	70%	98%	58%	58%	70%	60%	85%	65%
Maximum	100%	100%	100%	100%	100%	100%	100%	100%
Average	94%	100%	93%	92%	93%	92%	95%	88%
Weighted Average	81%	99%	86%	86%	83%	87%	97%	65%
Manufacturer Reps								
Minimum	70%	40%	70%	70%	1%	90%	30%	95%
Maximum	100%	100%	100%	100%	100%	100%	100%	100%
Average	96%	92%	94%	96%	84%	98%	91%	97%
Weighted Average	96%	93%	95%	97%	87%	98%	93%	95%
Weighted Average across both Market Actor Types	86%	97%	89%	90%	84%	90%	95%	75%²³

Table 17 shows that LEDs comprise the majority of sales for each product category.

- ◆ The lower value for streetlighting (86%) was driven by one large manufacturer (who used their database to pull up actual sales numbers – so therefore had a high weight), who reported that streetlighting was the one laggard to LED adoption and that LEDs comprised 70% of this category, with HPS and LPS comprising the remainder of sales. For comparison, this same manufacturer reported that all other exterior lighting product categories are 100% LEDs.
- ◆ The lower value for bollards (84%) was driven by one manufacturer rep who reported that “bollards are still spec’d as HPS, so LEDs comprise only about 1%”.
- ◆ The lower value for street sign lighting (75%) was driven by one manufacturer (with a medium weighting) who reported that 65% of sales are LEDs. Because TRC had responses from only three manufacturers for this product category, the one respondent’s estimate brought the average down.

Only one manufacturer sold pool lighting, and this respondent reported that 50% of sales for this product category are LEDs.

In general, TRC did not hear consistent differences by category across the 28 market actors surveyed. A few market actors called out a product category as a laggard to LED adoption, but that product category varied by market actor. Consequently, TRC recommends that the IOUs assume the average values across all exterior lighting products: 94% LEDs for all product categories²⁴.

²³Includes responses from only three manufacturers and three manufacturer reps.

²⁴ This does not include street sign lighting or pool lighting, because this study did not collect sufficient data to determine standard practices for those categories due to a scope change.

4.1.2 Projections of LED Market Penetration

TRC collected projection of LED market penetration for each type of market actor surveyed. TRC asked manufacturers and manufacturer reps to detail two and five-year LED projections for both new construction and retrofits. TRC asked maintenance contractors to provide a two and five-year LED projection for new construction and retrofits combined. The difference in manufacturers’ and manufacturer reps’ projections between new construction and retrofits was 0-1%. Because these differences are so small, and since maintenance contractors provided responses for the combined market of new construction and retrofits, TRC assumed the italicized values in Table 18, which average the values for new construction and retrofits, for market projections.

Table 18: Projections of LED Penetration by Market Actor

	New Construction		Retrofit		Combined: NC and Retrofit	
	2 Years	5 Years	2 Years	5 Years	2 Years	5 Years
Manufacturers						
Minimum	93%	98%	98%	99%	96%	99%
Maximum	100%	100%	99%	100%	100%	100%
Average	98%	100%	99%	100%	98%	100%
Weighted Average	98%	99%	98%	100%	98%	100%
Manufacturer Reps						
Minimum	80%	90%	85%	93%	83%	92%
Maximum	100%	100%	100%	100%	100%	100%
Average	97%	98%	98%	99%	97%	98%
Weighted Average	98%	98%	98%	98%	98%	98%
Maintenance Contractors						
Minimum					60%	70%
Maximum			N/A		100%	100%
Average					92%	95%
Weighted Average					96%	98%
Weighted Average across all Market Actors					98%	99%

For comparison, Table 19 provides national LED market penetration estimates from the Department of Energy (DOE). LED market penetration in California exceeds national LED market penetration. Ultimately, TRC believes our market actor survey results provide the best prediction of penetration by technology for the California market, because they are specific to California and were collected recently (in 2018).

Table 19: National Projection of LED Penetration for Outdoor Lighting (DOE, 2014)²⁵

Year	2013	2015	2020	2025	2030
LED Market Share (% of lm-hr sales)	9%	22%	75%	97%	99%

²⁵ DOE defined outdoor lighting to include street/roadway, parking (lots and garages), and building exterior.

4.2 Standard Practice LED Efficacy and Pricing

4.2.1 Efficacy Ranges for Available Products

The following graphs show efficacy results for each product category based on our data collected from manufacturer reps as part of the price quote process, and from online retailers. These figures group efficacy according to DLC designation and by DLC output grouping. The values represent product availability because they show the values before TRC weighted them by market actor responses to the question of the percent of sales by DLC-designation. Section 7.6 provides figures that show the efficacy of each product identified, for each project category (Figure 29 through Figure 35).

Figure 2: 2018 Non-DLC Qualified Lighting Product Efficacy by Output Group

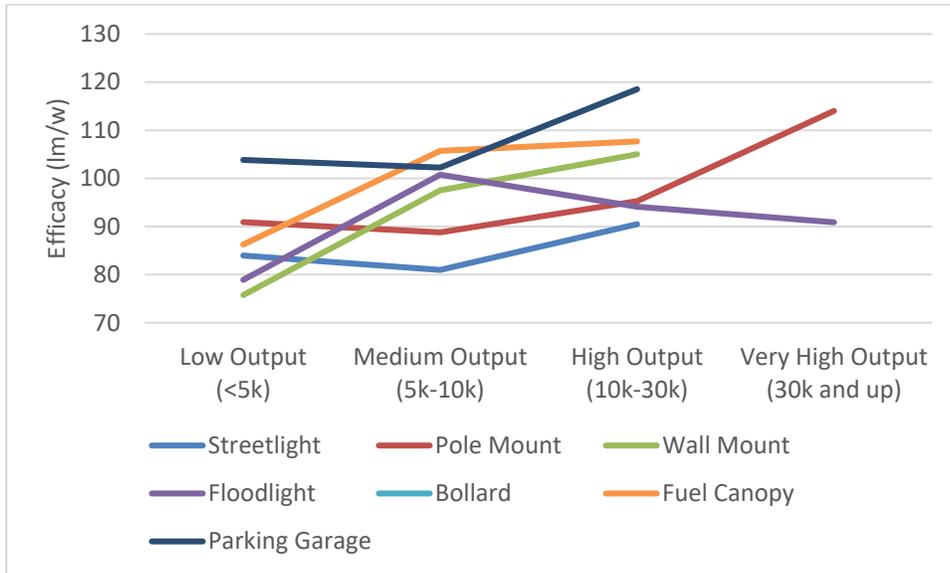


Figure 3: 2018 DLC Standard Qualified Lighting Product Efficacy by Output Group

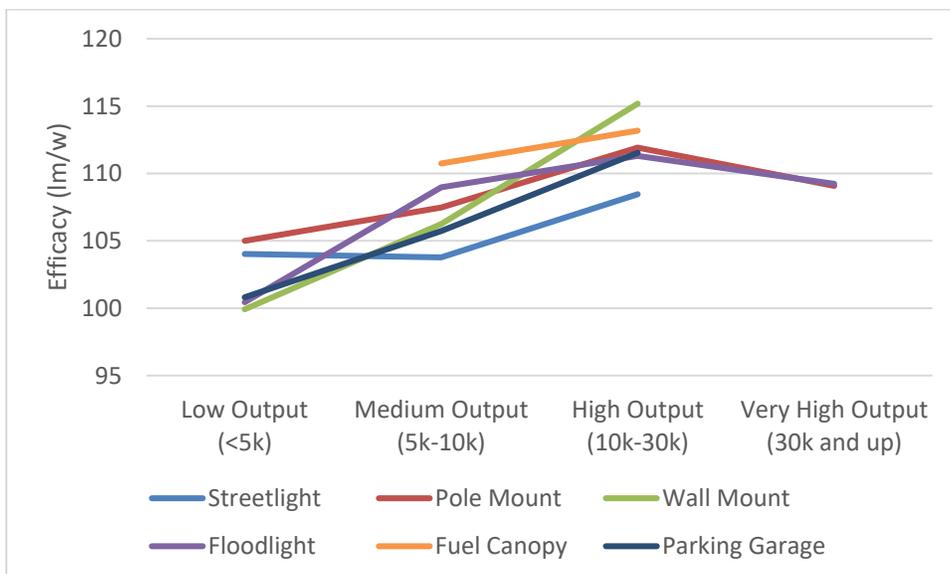
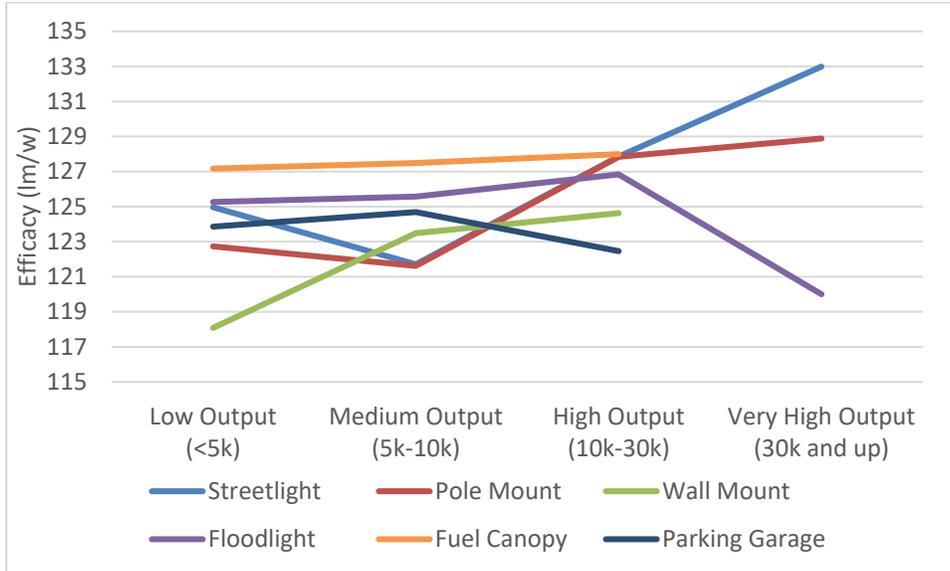


Figure 4: 2018 DLC Premium Qualified Lighting Product Efficacy by Output Group



By definition, DLC Premium products have a higher efficacy than DLC Standard products. However, since efficacy is not the only metric used to determine the DLC rating, there are a few non-DLC rated products that have equal efficacy with rated products, but this is somewhat an anomaly. Most non-DLC products have lower efficacy than both DLC Standard and DLC Premium products.

4.2.2 Pricing Ranges for Available Products

The following graphs show pricing results for each product category, based on our data collected from manufacturer reps as part of the price quote process, and from online retailers. Like the efficacy tables, these pricing tables represent product availability, because they show the values before TRC weighted them by market actor responses to the question of the percent of sales by DLC-designation.

Figure 5: 2018 Non-DLC Qualified Lighting Product Price by Output

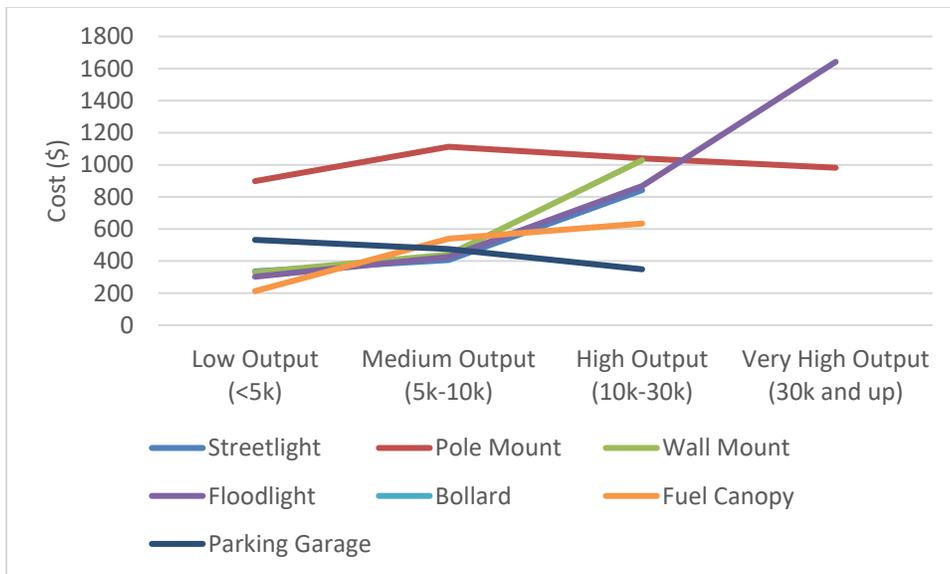


Figure 6: 2018 DLC Standard Qualified Lighting Product Price by Output

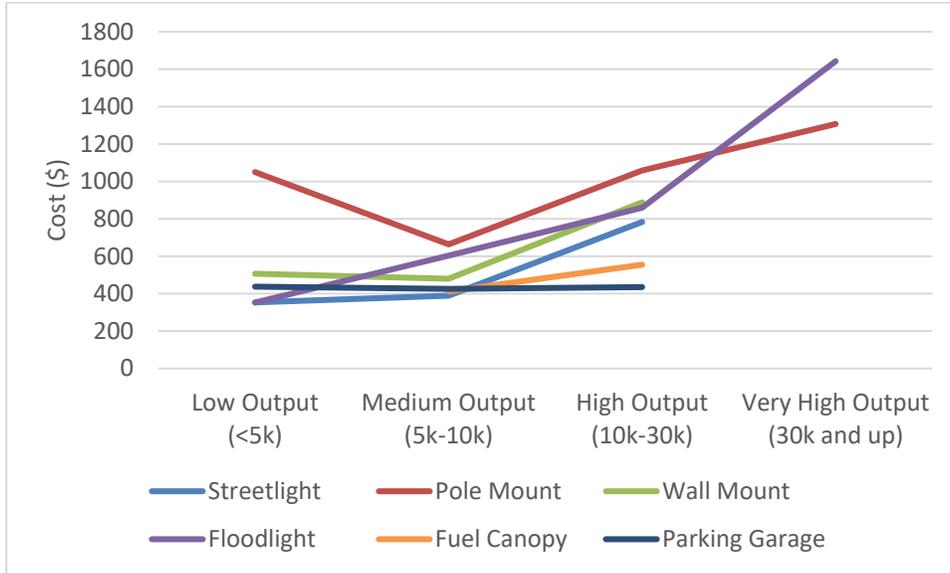
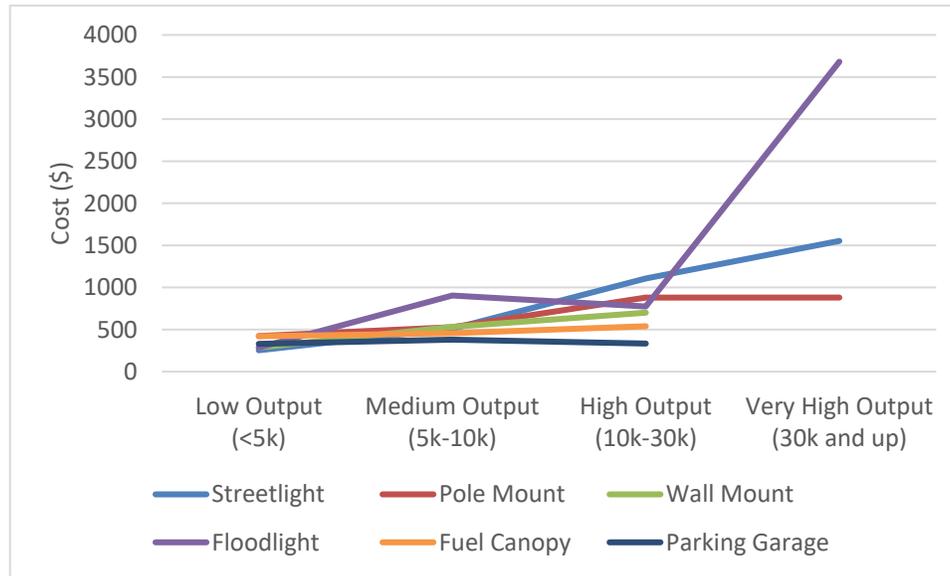


Figure 7: 2018 DLC Premium Qualified Lighting Product Price by Output



The following tables provide 2018 pricing information for the product categories.

Table 20: 2018 Pricing Results by DLC Designation: Streetlight and Pole Mount Fixtures

Current Costs		Streetlight			Pole Mount		
Lumens		Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium
<5k	Min	\$250	\$248	\$165	\$205	\$1,050	\$322
	Max	\$506	\$1,050	\$449	\$1,641	\$1,050	\$1,114
	Median	\$305	\$254	\$215	\$1,062	\$1,050	\$397
	Mean	\$336	\$353	\$253	\$898	\$1,050	\$423
	Qty	7	6	11	13	1	10
5k-10k	Min	\$250	\$220	\$251	\$335	\$380	\$359
	Max	\$918	\$1,173	\$1,177	\$2,568	\$1,292	\$1,177
	Median	\$439	\$317	\$483	\$1,148	\$566	\$523
	Mean	\$406	\$389	\$508	\$1,112	\$664	\$527
	Qty	20	22	12	19	9	12
10k-30k	Min	\$302	\$325	\$380	\$551	\$382	\$232
	Max	\$1,437	\$1,830	\$2,391	\$1,921	\$1,830	\$2,391
	Median	\$893	\$931	\$1,099	\$1,205	\$1,119	\$1,072
	Mean	\$842	\$783	\$1,106	\$1,040	\$1,058	\$879
	Qty	28	35	22	11	39	50
30k and up	Min	N/A	N/A	\$1,552	\$717	\$569	\$406
	Max	N/A	N/A	\$1,552	\$1,295	\$1,916	\$2,321
	Median	N/A	N/A	\$1,552	\$1,003	\$1,339	\$1,015
	Mean	N/A	N/A	\$1,552	\$982	\$1,307	\$880
	Qty	0	0	2	4	21	12

Table 21: 2018 Pricing Results by DLC Designation: Wall-mount and Floodlight Fixtures

Current Costs		Wall Mount			Floodlight		
Lumens		Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium
<5k	Min	\$69	\$247	\$126	\$90	\$124	\$150
	Max	\$1,281	\$1,083	\$722	\$853	\$1,225	\$819
	Median	\$403	\$395	\$279	\$333	\$348	\$245
	Mean	\$330	\$507	\$286	\$302	\$352	\$285
	Qty	63	13	12	25	13	4
5k-10k	Min	\$113	\$166	\$185	\$166	\$283	\$636
	Max	\$1,234	\$870	\$920	\$1,070	\$1,383	\$1,444
	Median	\$504	\$520	\$740	\$523	\$756	\$853
	Mean	\$441	\$480	\$532	\$426	\$604	\$904
	Qty	18	11	5	16	8	4
10k-30k	Min	\$562	\$533	\$700	\$543	\$230	\$493
	Max	\$1,307	\$1,295	\$700	\$1,243	\$2,763	\$1,567
	Median	\$1,157	\$930	\$700	\$838	\$888	\$618
	Mean	\$1,029	\$888	\$700	\$868	\$860	\$773
	Qty	5	7	1	13	17	5
30k and up	Min	N/A	N/A	N/A	\$1,378	\$697	\$3,682
	Max	N/A	N/A	N/A	\$1,916	\$4,121	\$3,682
	Median	N/A	N/A	N/A	\$1,658	\$1,817	\$3,682
	Mean	N/A	N/A	N/A	\$1,642	\$1,643	\$3,682
	Qty	0	0	0	5	6	1

Table 22: 2018 Pricing Results by DLC Designation: Bollard and Fuel Canopy Fixtures

Current Costs		Bollard			Fuel Canopy		
Lumens		Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium
<5k	Min	\$300	N/A	N/A	\$91	N/A	\$216
	Max	\$1,881	N/A	N/A	\$670	N/A	\$1,000
	Median	\$849	N/A	N/A	\$212	N/A	\$351
	Mean	\$818	N/A	N/A	\$212	N/A	\$420
	Qty	32	0	0	8	0	10
5k-10k	Min	N/A	N/A	N/A	\$390	\$390	\$143
	Max	N/A	N/A	N/A	\$722	\$440	\$1,099
	Median	N/A	N/A	N/A	\$514	\$411	\$423
	Mean	N/A	N/A	N/A	\$540	\$412	\$455
	Qty	0	0	0	5	4	13
10k-30k	Min	N/A	N/A	N/A	\$440	\$376	\$340
	Max	N/A	N/A	N/A	\$774	\$831	\$1,277
	Median	N/A	N/A	N/A	\$748	\$565	\$452
	Mean	N/A	N/A	N/A	\$634	\$555	\$539
	Qty	0	0	0	3	4	8

Table 23: 2018 Pricing Results by DLC Designation: Parking Garage

Current Costs		Parking Garage		
Lumens		Non-DLC	DLC Standard	DLC Premium
<5k	Min	\$180	\$245	\$169
	Max	\$930	\$954	\$785
	Median	\$598	\$348	\$340
	Mean	\$532	\$438	\$330
	Qty	6	6	9
5k-10k	Min	\$190	\$195	\$176
	Max	\$909	\$1,201	\$848
	Median	\$823	\$397	\$377
	Mean	\$475	\$426	\$380
	Qty	7	23	14
10k-30k	Min	\$190	\$273	\$195
	Max	\$560	\$598	\$598
	Median	\$398	\$449	\$390
	Mean	\$349	\$435	\$333
	Qty	3	6	8

TRC did not identify bollard, fuel canopy products, or parking garage fixtures greater than 30,000 lumens.

TRC found wide ranges and no clear patterns in pricing seen in Figure 8 and Figure 9. Many product groups had a maximum price more than three or four times the minimum price. TRC found no clear pattern in pricing between DLC-listed and non-DLC products. For some categories, the mean price for DLC Standard products was lower than for DLC Premium products, but in other categories, the DLC Premium products were less expensive. Navigant (2018) found a similar result in that there was no clear pricing trend based on DLC designation. Section 7.6 in the appendix provides graphs of price versus lumen output for each product category. Those figures show some correlation in price compared with output.

The high pricing variability is likely attributable to several factors, including aesthetics, product construction quality, product optical performance quality, and other features like configurability and added integrated controls.

Figure 7 and Figure 8 below provide a graphical presentation of the variety of data collected for the Streetlight category of products. The first shows the price plotted against the lumen output for streetlights; there is a trend that price increases with output. However, note that the range of possible prices for the products is very high, ranging from approximately \$150 up to \$2400. Even removing outliers, the range of product pricing is still quite large.

Figure 8: 2018 Price versus Output: Streetlight

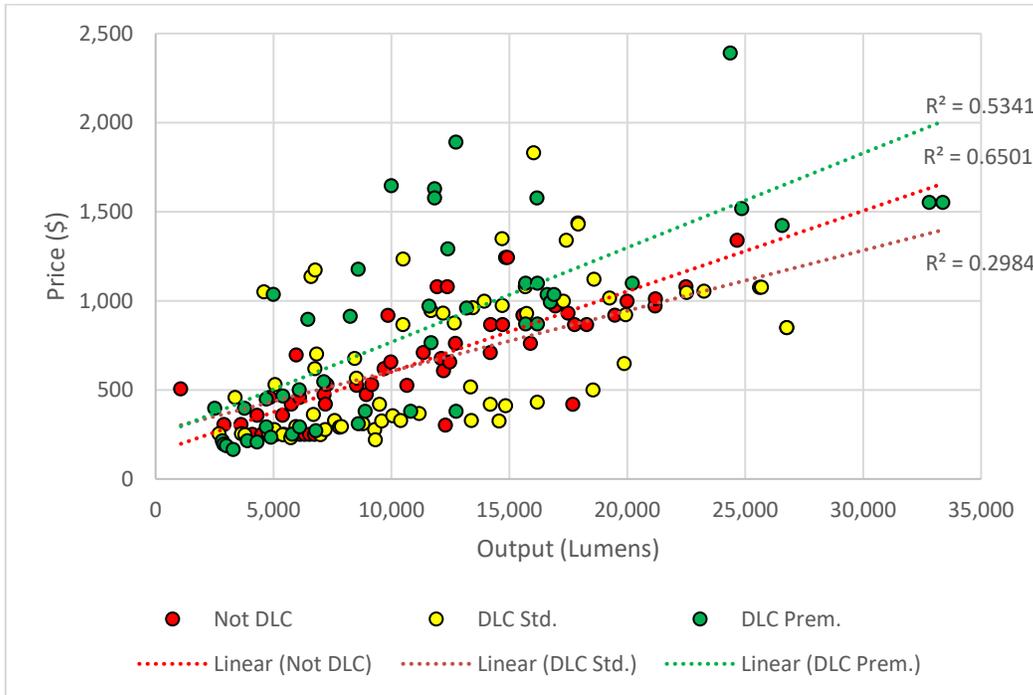
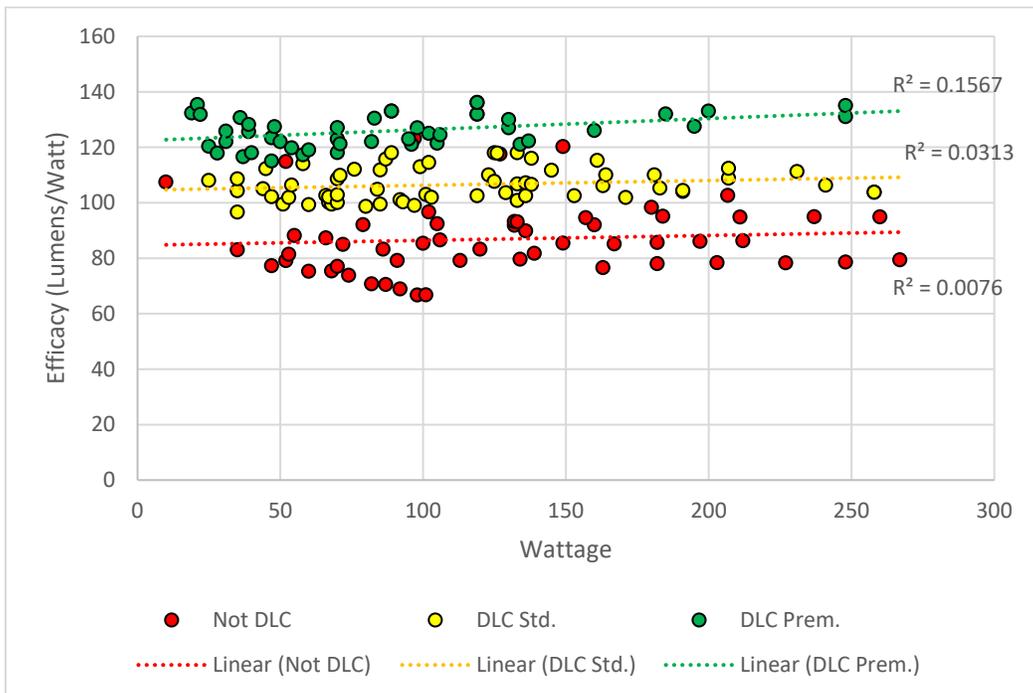


Figure 9 shows the same products plotted as wattage against efficacy. It is possible to see that there are clear ranges of performance available in the streetlight category, and the most efficacious products have an efficacy almost twice that of the least efficacious products.

Figure 9: 2018 Wattage versus Efficacy: Streetlight



4.2.3 Sales by DLC Designation

Table 24 shows results of market actor responses to product sales / installations by DLC-designation for overall exterior lighting sales.

Table 24: Market Actor Estimates of Sales by DLC Designation for all Exterior Lighting Fixtures

	New Construction				Retrofit				Combined			
	DLC Prem.	DLC Std.	DLC Listed	Non-DLC	DLC Prem.	DLC Std.	DLC Listed	Non-DLC	DLC Prem.	DLC Std.	DLC Listed	Non-DLC
Manufacturers												
Minimum									5%	45%	80%	2%
Maximum									45%	88%	98%	20%
Average									24%	68%	92%	9%
Weighted Average									23%	70%	93%	7%
Manufacturer Reps												
Minimum	0%	0%	50%	0%	10%	0%	63%	0%				
Maximum	100%	100%	100%	50%	100%	75%	100%	38%				
Average	39%	46%	82%	18%	50%	37%	89%	11%	45%	42%	86%	15%
Weighted Average	40%	42%	84%	16%	54%	28%	86%	14%	47%	35%	85%	15%
Maintenance Contractors												
Minimum									10%	0%	70%	0%
Maximum									100%	60%	100%	30%
Average									66%	27%	91%	8%
Weighted Average									75%	22%	96%	5%
Weighted Average across all Market Actors									37%	53%	91%	9%
Weighted Average across Manufacturers and Manufacture Reps									31%	58%	90%	10%

Several maintenance contractors were IOU referrals and responded that many of their installations were DLC Premium to receive utility rebates, so may not have represented the broader market for this question. A few other could not reliably estimate their split between DLC Premium and DLC Standard products. Consequently, TRC believes that the most accurate values for the splits by DLC designation are shown in the last row of Table 24, which includes manufacturer and manufacturer rep responses but not maintenance contractor responses.

In addition to asking market actors for their overall estimate of sales/installations across all exterior lighting fixtures by DLC designation (results shown in Table 24), TRC also asked market actors to estimate their sales/installations by DLC designation (% DLC Premium, % DLC Standard, and % Non-DLC listed) for each product category. Table 64 in the Appendix shows results. In general, responses to sales by DLC designation were similar for the different product categories. For simplicity, and because some product categories had DLC designation estimates from only a few market actors, TRC assumed the values for all exterior lighting sales shown in the last row of Table 24 as the weights for all product categories, for estimating standard practice efficacy and pricing for LEDs: 31% DLC Premium, 58% DLC Standard, and 10% not DLC listed.

4.2.4 Standard Practice for LED Fixture Efficacy

Table 25 shows standard practice efficacy results for each product category. As described in Section 3.4, TRC calculated a weighted average, using the mean efficacy for each DLC-designation and assuming 31% DLC Premium, 58% DLC Standard, and 10% not DLC listed²⁶.

Figure 10 below shows the average efficacy of the various lighting product categories broken down by DLC output grouping. This shows that on average, many of the categories are somewhat comparable in output, except for the Bollard category, which is substantially below the rest.

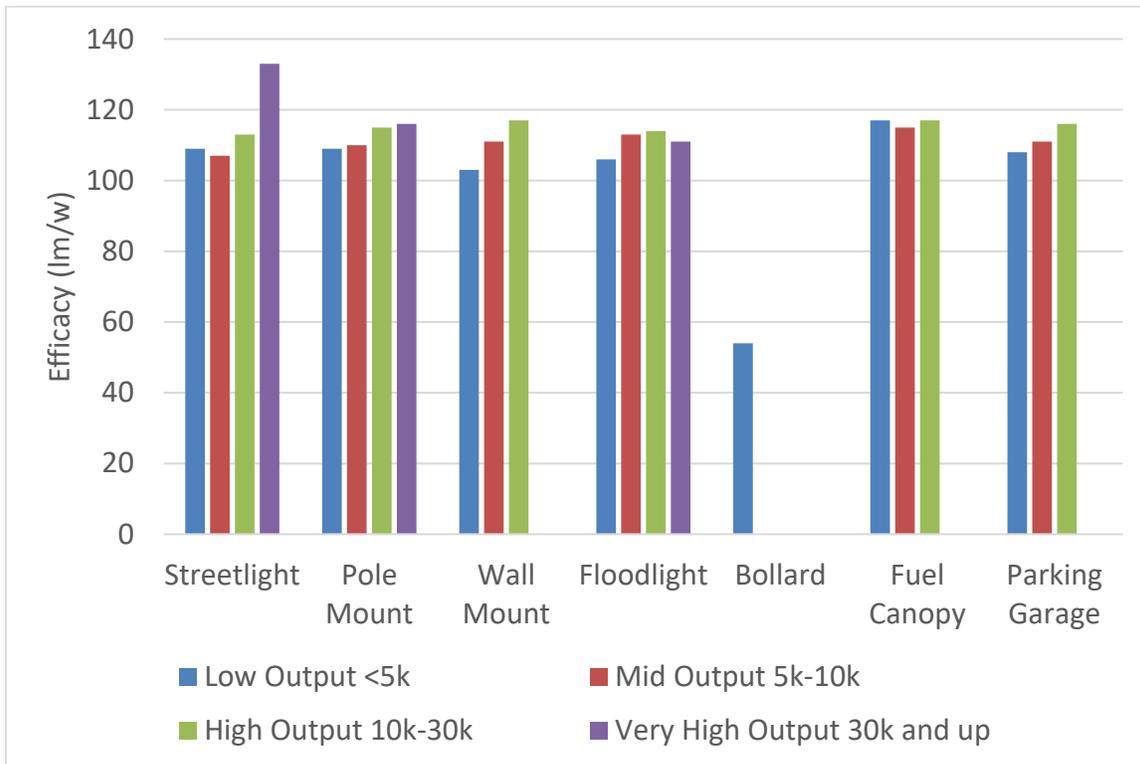
Table 25: 2018 Standard Practice Efficacy Estimate by Product Category

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	109	109	103	106	54	117	108
Mid Output 5k-10k	107	110	111	113	N/A	115	111
High Output 10k-30k	113	115	117	114	N/A	117	116
Very High Output 30k and up	133	116	N/A	111	N/A	N/A	N/A

Standard practice efficacy is approximately 100 Lm/W or slightly higher for most categories except bollards. For bollards, efficacy is approximately 54 Lm/W.

²⁶ Results do not total to 100% because of rounding. The full values are: 58.4% DLC Standard, 31.4% DLC Premium, and 10.2% non-DLC.

Figure 10: 2018 Standard Practice Efficacy Estimate by Product Category



Based on market actor surveys, most products are DLC Standard. Our product review found that the efficacy of DLC Standard products ranged from approximately 11 LPW lower to 10 LPW higher than the average product. Consequently, TRC estimates that our standard practice efficacy results are accurate within approximately 10%.

4.2.5 Standard Practice Pricing

TRC used the same weighting approach to estimate standard practice pricing – assuming 31% DLC Premium, 58% DLC Standard, and 10% non-DLC, for each product category of exterior fixtures. Table 26 presents the results.

Table 26: 2018 Standard Practice Pricing Estimate by Product Category

2018 Fixture Cost	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$320	\$838	\$420	\$326	\$818	\$369	\$413
Mid Output 5k-10k	\$428	\$667	\$492	\$680	N/A	\$439	\$416
High Output 10k-30k	\$891	\$1,000	\$844	\$833	N/A	\$558	\$394
Very High Output 30k and up	\$1,552	\$1,140	N/A	\$2,283	N/A	N/A	N/A

Given the large range of prices within product category, these estimates for standard practice pricing have low accuracy.

4.3 Efficacy projections for 2019 - 2023

This section provides estimates of efficacy projections. As a starting point, TRC used our mean efficacy results for each group of products, presented in Table 25. TRC then projected those values forward to 2023, by assuming an average efficacy increase based on published studies.

Table 27 provides the efficacy projections for different categories of LED lamps and fixtures from DOE (2014). These projections use the rate of efficacy increase from the SSL Pricing and Efficacy Trend Analysis for Utility Program Planning report prepared by Pacific Northwest National Laboratory (PNNL) for the DOE in October 2013. As shown in Table 27, DOE predicts an average annual efficacy increase for LED fixtures of 3-4%.

Table 27: National LED Efficacy Projections (DOE 2014)

Submarkets	LED Fixture Efficacy			Fixture Efficacy Increase (%/yr)	
	2015	2020	2023	2015-2020	2020-2023
Street/Roadway	92	111	122	3.8%	3.3%
Parking Lot	92	111	122	3.8%	3.3%
Parking Garage	91	106	115	3.1%	2.8%
Building Exterior	91	106	115	3.1%	2.8%
Other	91	106	115	3.1%	2.8%

In 2017, DOE provided updates in the SSL 2017 Suggested Research Topics report that includes projections for the efficacy increase of LED packages for phosphor coated LEDs. That report (DOE 2017b) does not include luminaire (fixture) efficacy, but only the efficacy of the LED chip package, so these values are not meant directly comparable to the efficacy of the fixtures in Table 27 above. The annual percentage change in efficacy is useful to compare, and these values are factored into the efficacy projections below. As shown in Table 28 below, the efficacy improves approximately 3.8% from 2014 through 2020, and 3.3% from 2020 through 2023.

Table 28: LED Package Efficacy Projections (DOE 2017b)

Submarkets	LED Package Efficacy				Efficacy Increase (%/yr)	
	2014	2016	2020	2023	2014-2020	2020-2023
Warm White	131	137	208	237	3.8%	3.3%

Because the DOE (2014) projection was more directly applicable to outdoor fixtures, but the DOE (2017b) projection was more recent, TRC used an average value of the reports and assumed that efficacy would increase for all product categories by 3.3% annually. Table 29 shows our mean efficacy projections for each group of products in 2023. A full set of tables for each year is available in Section 7.6.5 in the appendices.

Table 29: LED Efficacy Projections for 2023

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	128	128	121	125	64	138	127
Mid Output 5k-10k	126	129	130	133	N/A	136	131
High Output 10k-30k	133	136	180	135	N/A	138	136
Very High Output 30k and up	156	136	N/A	143	N/A	N/A	N/A

Figure 11, Figure 12, and Figure 13 show the efficacy of the various lighting product categories based on the DLC output groups for 2023. There is a clear trend toward high efficacy as the output increases.

Figure 11: 2023 Non-DLC Qualified Lighting Product Efficacy by Output Group

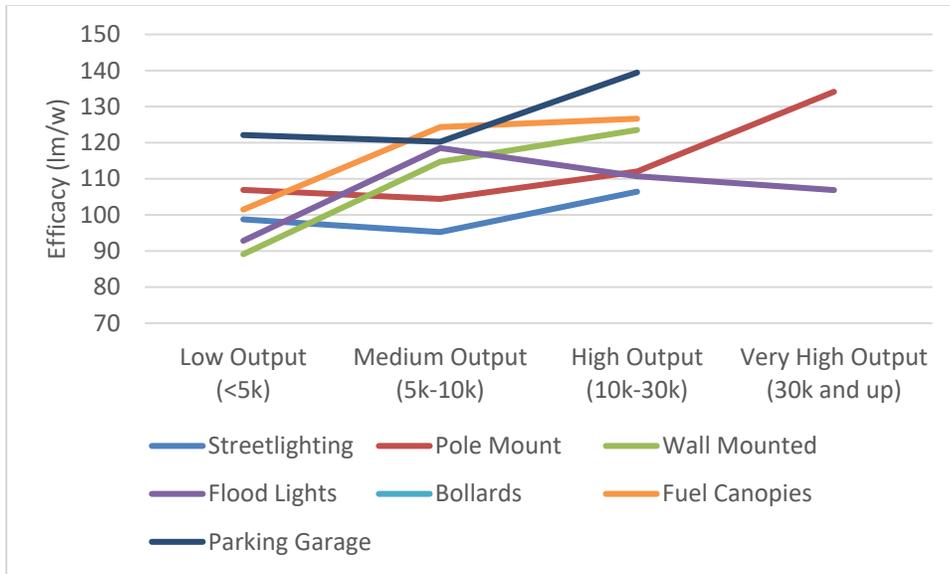


Figure 12: 2023 DLC Standard Qualified Lighting Product Efficacy by Output Group

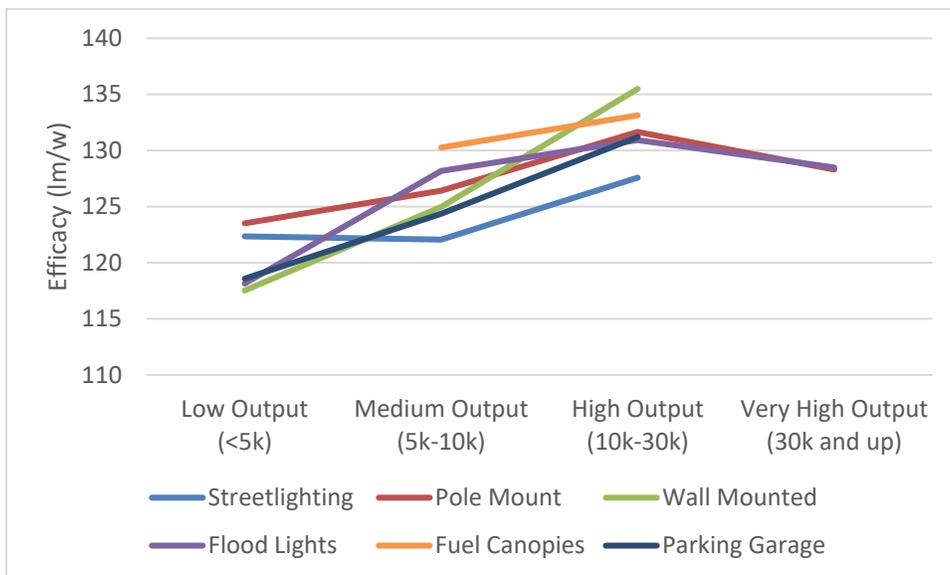
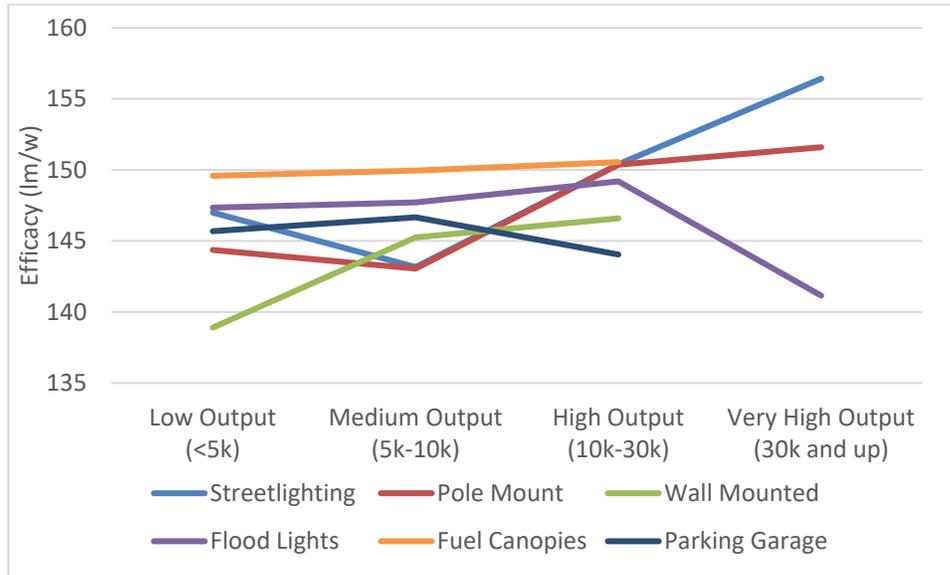


Figure 13: 2023 DLC Premium Qualified Lighting Product Efficacy by Output Group



4.4 Price Projections for 2019 - 2023

TRC identified three projections for LED pricing in the literature.

- ◆ Freedonia (2018) estimates that prices for outdoor LED fixture will *increase* 1.4% annually through 2022. Freedonia cited increases in energy efficiency and smart features as reasons why fixture prices will increase.
- ◆ DOE (2014) estimates that prices for outdoor LED fixtures will *decrease* 7% annually from 2015 through 2020 and decrease 6% annually from 2020 to 2030. This report is based on an estimate of the price changes for the *same fixtures*, so does not account for new products entering the market.
- ◆ Navigant (2018) estimates that prices for exterior LED fixtures will decrease at a declining rate. As shown in Table 30, Navigant estimated that LED exterior fixture prices will drop 11% from 2018 to 2019, and 7% from 2022 to 2023.²⁷

Table 30: Price Decrease Compared to Previous Year, Assumed by Navigant (2018)

2019	2020	2021	2022	2023
-11%	-9%	-8%	-8%	-7%

None of these studies account for inflation. All three studies assume similar product categories for outdoor fixtures, including streetlighting, parking lot, parking garage, and wall-mounted fixtures.

Given the variation of pricing projections in the literature, it is difficult to predict product pricing. As shown in Section 4.2.2, TRC found considerable scatter in pricing for fixtures in the same product group, and no clear trend in pricing based on DLC-designation. It is possible that products may increase in price for the reasons described by Freedonia (2018). In addition, manufacturers may use more expensive LED drivers to increase

²⁷ Navigant projected that each exterior lighting product category will decline at slightly different rates. For simplicity, and because there is no clear evidence that price declines will vary by product category, TRC averaged Navigant’s price decline rates across all exterior product categories.

efficacy, higher quality plastic or reflector materials to improve optical design, or integrate internet-of-things capabilities, partly to enable them to charge more for products. TRC also heard anecdotally from manufacturer reps as part of the price quote process that prices may increase because of recent federal government tariffs on imported goods. It is also possible that pricing will decrease, due to advancements in LED chips.

To inform our decision of which projection to use, TRC compared our pricing data sets with the DOE price estimate for 2018 and compared our pricing (collected in Q3 2018) with the pricing that Navigant (2018) found in their data (collected Q4 2016-Q2 2017) to look for temporal trends.

4.4.1 Price per Lumen Comparison

TRC calculated the price per kilolumen (kLm) for TRC’s pricing survey results and the Navigant data set for comparison with projections from the DOE projection (2014) for 2018. TRC estimated the DOE projection for 2018 by interpolating between the DOE projection for 2015 (\$42/kLm) and 2020 (\$27/kLm) for all outdoor fixtures, for an estimated value of \$31.20 per kLm. Table 31 and Table 32 provide a comparison summary of the information from the various sources. Blank values in these tables indicate that the data set did not cover this product category.

Table 31: Price per kLm in Navigant Data, TRC Data, and DOE Projections: Streetlight, Pole Mount, Wall Mount and Floodlight

Price per kLm	Streetlight	Pole Mount	Wall Mount	Floodlight
Navigant (2018): Data Collected Q4 2016 – Q2 2017	\$ 82.78	\$ 282.73	\$254.85	
TRC: Data Collected Q3 2018	\$ 69.26	\$ 106.40	\$160.53	\$ 126.43
DOE (2014) Projection for 2018	\$ 31.20		\$ 31.20	

Table 32: Price per kLm in Navigant Data, TRC Data, and DOE Projections: Bollard, Fuel Canopy, and Parking Garage Fixtures

Price per kLm	Bollard	Fuel Canopy	Parking Garage
Navigant (2018): Data Collected Q4 2016 – Q2 2017		\$ 121.96	\$ 128.57
TRC: Data Collected Q3 2018	\$ 813.05	\$ 69.56	\$ 75.61
DOE (2014) Projection for 2018			\$ 31.20

For all product categories, TRC’s data found a lower price per kilolumen than Navigant. This supports a conclusion that prices are decreasing.

It is worth noting that the price per kilolumen in the Navigant (2018) and TRC datasets are both significantly higher than the DOE projected cost for 2018. This is likely because the DOE projections are priced for the same fixtures over time. As described in Freedonia (2018), new products enter the market with additional features, which increase the average price for a product category.

4.4.2 Pricing Comparison in Navigant and TRC Data Sets

To further investigate how product pricing has changed, TRC reviewed products that appeared in the pricing data from Navigant (2018) and looked up their current pricing on the same online retailer website used by Navigant. For many products in the Navigant data set, TRC was unable to find them online, indicating that the retailers may have substituted them with different (probably newer) products. TRC was able to identify ten products for each product category covered in both our study and the Navigant (2018) study that were still for

sale on the retailer’s website used by Navigant. Table 33 shows results for their current price minus the pricing in Navigant (2018), divided by the Navigant price. A negative value indicates the price is lower currently than the price found by Navigant (2018).

Table 33: Pricing Comparison for Identical Products: Current Pricing (Q3 2018) Compared with Navigant Pricing (Collected Q2 2016 - Q4 2017)

	Streetlight	Wall Mount	Parking Lot	Garage	Fuel Canopy
	-12%	0%	2%	88%	0%
	0%	-43%	0%	0%	0%
	0%	-38%	0%	91%	8%
	0%	4%	0%	91%	0%
	0%	-1%	-31%	92%	91%
	-14%	44%	0%	91%	0%
	6%	-12%	0%	-4%	0%
	0%	0%	-42%	120%	0%
	-76%	-13%	-9%	0%	0%
	0%	0%	-28%	0%	-12%
Average	-10%	-6%	-11%	57%	9%
Standard Dev.	24%	24%	17%	51%	29%
Median	0%	0%	0%	90%	0%

As shown, there are few trends in pricing for these same products over time. Many products had the same price in both data sets, and the median change for most categories is 0%. Other products showed significant change in prices, with some products increasing in price – including most parking garage products, and others decreasing in price – including some streetlights and wall pack products. The average price decreased for three of the product categories.

The results were inconclusive for all categories other than garage lighting which showed a noticeable increase.

4.4.3 Price Projections

TRC found that the overall price per kLm had decreased in the Navigant data (collected 2016-2017) and our data (collected 2018). Consequently, TRC expects that pricing will decrease. To develop estimates of future price changes, TRC averaged the price rates projected by DOE (2014) and Navigant (2018). In addition, TRC added a price increase of 2.3% annually to account for inflation, based on data from the Bureau of Labor and Statistics²⁸.

Table 34 presents TRC’s estimate of price change compared to the previous year. As shown, TRC estimates that LED fixtures will decrease in price by 9% for 2019 compared to 2018, and by 5% for 2023 compared to 2022.

Table 34: LED Fixture Price Change Compared to Previous Year Used for Price Projections

	2019	2020	2021	2022	2023
	-9%	-7%	-6%	-6%	-5%

²⁸ <https://www.bls.gov/cpi/news.htm>

Note that these pricing projections do not include any impacts associated with tariffs. As the price quote work was being performed, new tariffs were announced on goods made in countries that are considered main suppliers for some of the materials used in lighting equipment, including electronics, LED chips, and raw materials. These prices may be impacted by these new tariffs, but TRC unsure by how much. A few manufacturer reps anecdotally reported that they were planning to try to shift suppliers in other countries to remain competitive, but they still anticipated some price increases.

TRC projected our 2018 prices in Section 4.2.5 forwards through 2023 by assuming the price decreases shown in Table 34. For bollards, fuel canopy fixtures, and parking garage fixtures, TRC did not identify products greater than 30,000 lumens, so there are no projections at that output level for those products. Table 35 show price projections for 2023. Section 7.6.2 presents similar tables for 2019-2022.

Table 35: Price Projections for 2023 Exterior Lighting Products

2023 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$202	\$529	\$265	\$206	\$516	\$233	\$261
Mid Output 5k-10k	\$270	\$421	\$310	\$429	N/A	\$277	\$263
High Output 10k-30k	\$562	\$631	\$532	\$526	N/A	\$352	\$249
Very High Output 30k and up	\$979	\$719	N/A	\$1,440	N/A	N/A	N/A

Figure 14, Figure 15, and Figure 16 show the projected 2023 pricing for the product categories broken down into DLC output groups.

Figure 14: 2023 Non-DLC Qualified Lighting Product Price by Output

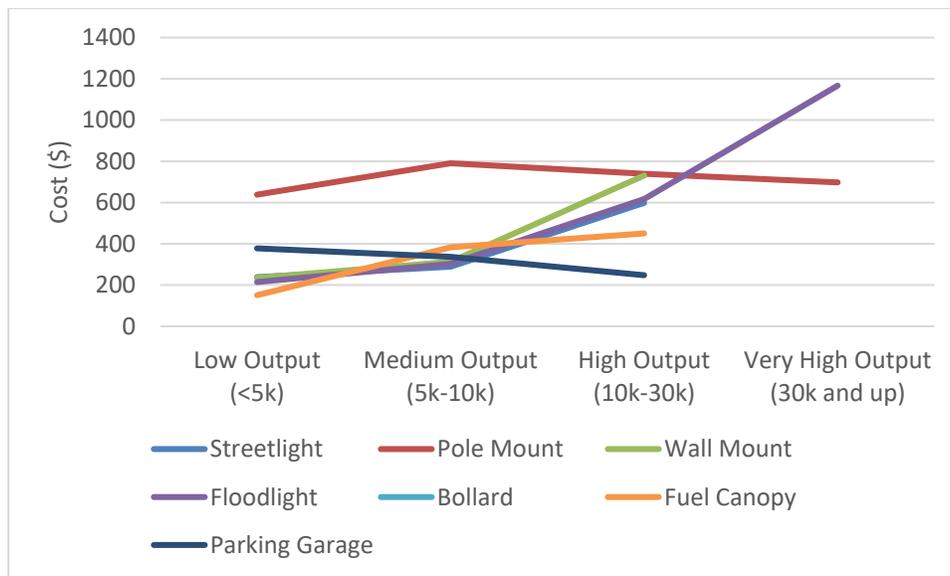


Figure 15: 2023 DLC Standard Qualified Lighting Product Price by Output

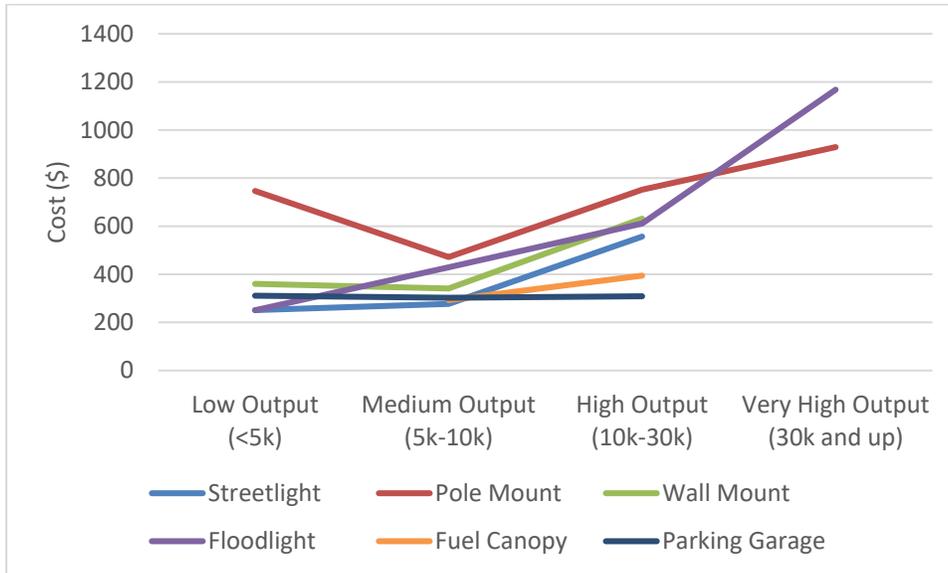
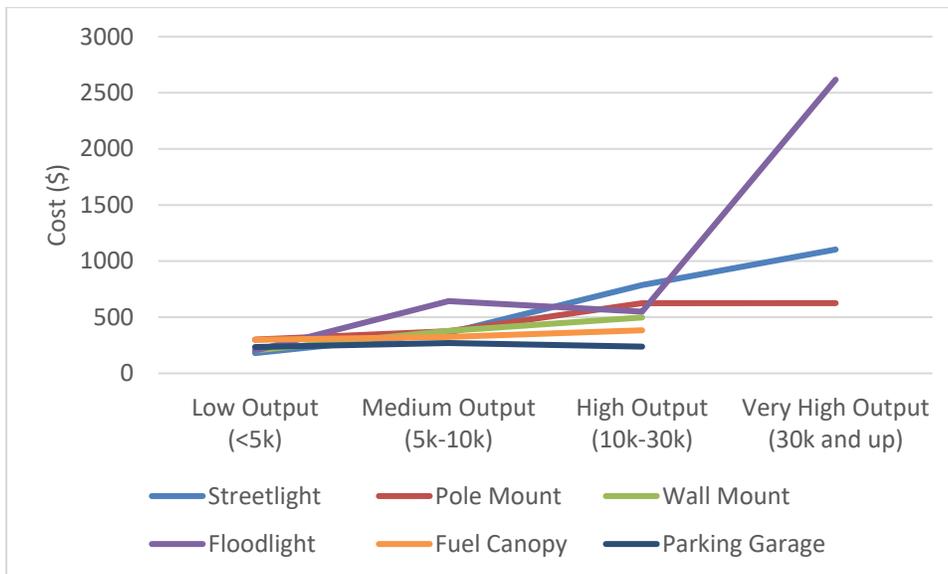


Figure 16: 2023 DLC Premium Qualified Lighting Product Price by Output



These price projections have low precision, given the wide range of pricing that TRC identified within each product group, and given the disagreement in price change projections in the literature.

4.5 Comparison of Standard Practices and Title 24-2019 Requirements

Consistent with past iterations of Title 24, Title 24-2019 does not specify minimum efficacy requirements for exterior lighting (referred to as outdoor lighting in Title 24). Instead, Title 24-2019 specifies lighting power allowance (LPA) requirements based on modeled scenarios. Some of the Title 24 products used in the outdoor lighting CASE analysis align with the exterior lighting categories in this study.

The following product categories have a comparable allowance category in the Title 24 analysis: pole-mounted fixtures are used in the general hardscape allowance, wall mounted fixtures are used in the building entrance and exit allowance, floodlighting equipment is used in the facade allowance, and fuel canopies fixtures are used in the vehicle service station canopy allowance. Title 24 does not have specific allowances for streetlighting, pool

lighting, street sign lighting, or bollards. Also, Title 24 regulates parking garage lighting as interior unconditioned space rather than exterior lighting. All of these types of lighting products may be used in the outdoor lighting allowances within Title 24, but the models developed for the calculation of the allowances do not include them in any appreciable manner.

The general hardscape allowance calculations in Title 24-2019 is based on lighting equipment that is most suitable for parking lot applications. This corresponds closely to the Pole Mount category in this study and represents approximately 50% of the total energy consumption found in Title 24 energy modelling of the outdoor lighting for the state. The efficacy of the equipment modelled in the Title 24-2019 CASE report averages to the following for each lighting Zone (LZ), as seen in Table 36 below.

Table 36: Title 24-2019 Efficacy Comparison for Pole Mount Category

Title 24-2019 Weighted Efficacy for General Hardscape (Lm/W)					
LZ1-A	LZ2-A	LZ2-C	LZ3-A	LZ3-C	LZ4-A
88	91	92	92	93	94
Collected Pole Mount Product Efficacy (Lm/W)					
113					

There are four LZ’s represented, from LZ1 (undeveloped regions and developed areas in parks) to LZ4 (the most urban developed regions of the state). Note that the LZ4 designation is not applied to a region without application to the California Energy Commission; the default urban districts are LZ3. As of this time, there are no LZ4 regions in the state.

Additionally, due to a change in the lighting design criteria for parking lots that now changes depending on the reflectivity of the ground surface (asphalt or concrete), there are two different LPA values included in Title 24-2019. These are designated by the “-A” (asphalt) and “-C” (concrete) modifiers in the category headings.

At lower output levels, as a lighting product increases in light output, the efficacy will increase because the percentage of output lost to driver inefficiency decreases. This is reflected in the table, with the lowest (88 lumens per watt) in LZ1, and the highest (94 lumens per watt) in LZ4-A. The majority of the state development is presumed to be in the LZ3 categories based on the CASE report statements regarding the distribution of developed land.

Table 37 shows the efficacy of the products in the Title 24-2019 CASE analysis, and the average efficacy for products collected by TRC. For the CASE analysis results, there is a single value because the context of the installations used for the Title 24-2019 modeling is a significant part of the results that may be presented in the table. The CASE team selected *appropriate* products for the context of the general hardscape designs within each LZ, and this will exclude high wattage products in the lower LZs, and lower wattage products in the high LZs. Since this analysis excludes the context employed in the CASE Report, we cannot weight the products in a similar manner. However, within that constraint, the pole-mount products collected by TRC have a higher efficacy compared to the Title 24-2019 baseline products by 20% (LZ4) to 28% (LZ1).

Table 37: Title 24-2019 Efficacy Comparison to TRC Standard Practice Findings

Application	Efficacy in T24-2019 CASE Analysis (Lm/W)				Avg. SP Efficacy in Products Collected by TRC (Lm/W)
	LZ1	LZ2	LZ3	LZ4	
Building Facades	48	58	68	73	99 (Floodlight)
Vehicle Service Station Canopy	70	70	67	65	117 (Fuel Canopy)
Building Entrance and Exit	63	66	70	77	94 (Wall Mount)

This comparison also shows that the products collected by TRC have a substantially higher efficacy than those used to develop the Title 24-2019 allowance tables. This could loosely be interpreted as showing that standard practice has a higher efficacy than code. However, project teams can choose to meet the code (LPA) requirements by adjusting their fixture spacing and/or fixture wattage, in addition to choosing products with higher efficacy. Within the code, the total power density is the only basis for evaluation, so there is not necessarily an improvement in the total building energy performance if a higher efficacy light fixture is chosen.

4.6 Installed Stock by Technology

This section provides results that indicate the installed (a.k.a. existing) stock of exterior lighting by technology and electricity use of that installed stock.

4.6.1 Results of TRC’s Model of Installed Exterior Lighting

Figure 17 shows results of our model of installed exterior lighting by technology: compact fluorescent (CFL), linear fluorescent (FL), incandescent or halogen (Inc/Hal), high pressure sodium (HPS), low pressure sodium (LPS), metal halide (MH), mercury vapor (MV) and LED. As noted in the Methodology section, these results include pole-mounted, wall mounted, flood and spot lighting, bollards, and fuel canopies, but exclude streetlighting, parking garages, pool lighting, and street sign lighting. This figure describes the y-axis as the number of lighting products; for HID and linear fluorescent products, these are generally fixtures, while these are generally lamps for incandescent, halogen, and CFL products.

Figure 17: Estimated Number of Exterior Lighting Products Installed in California, by Technology

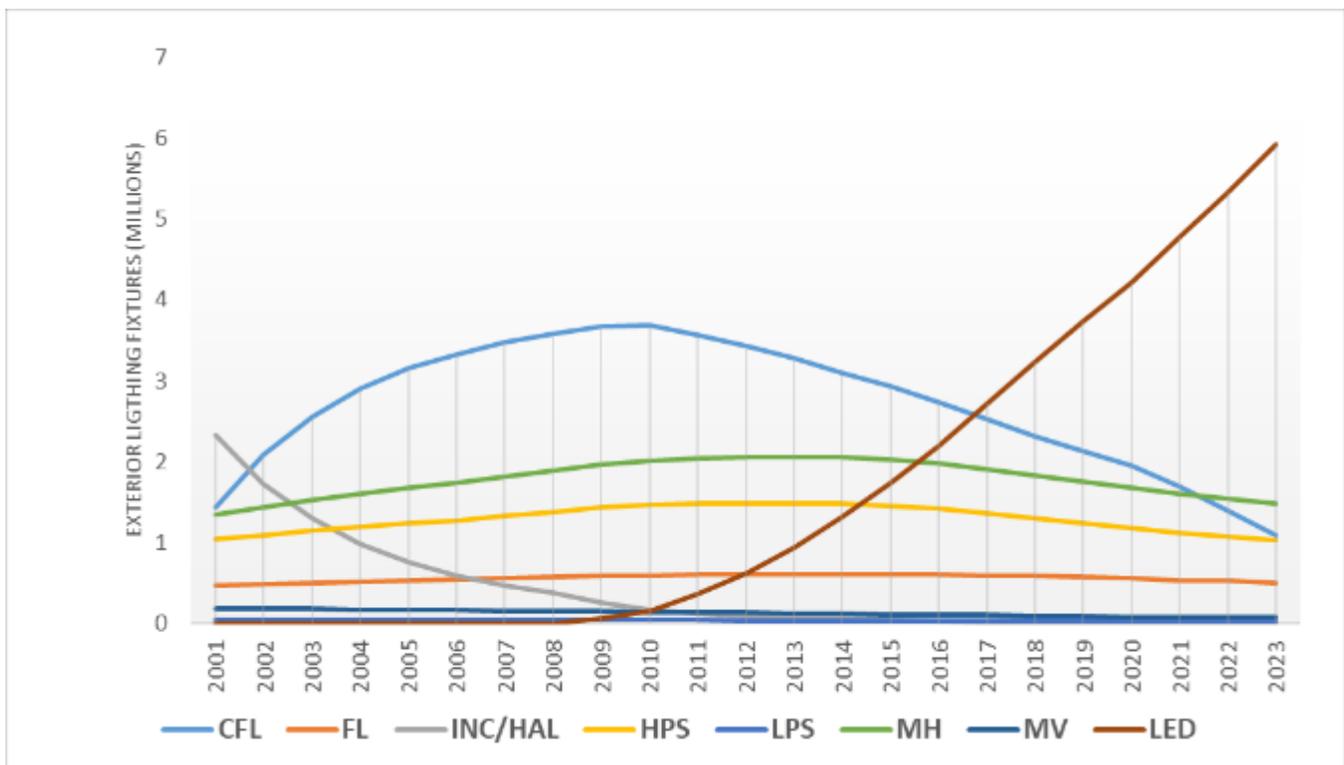


Figure 18 presents the same information, but with HID technologies (HPS, LPS, MH, and MV) grouped together. Showing all HID technologies as one group illustrates the dominance of this category (especially considering that this data does not include street and highway lighting) and enables comparison to past studies in Section 4.6.3.

Figure 18: Estimated Number of Exterior Lighting Products Installed in California, HID Technologies Aggregated

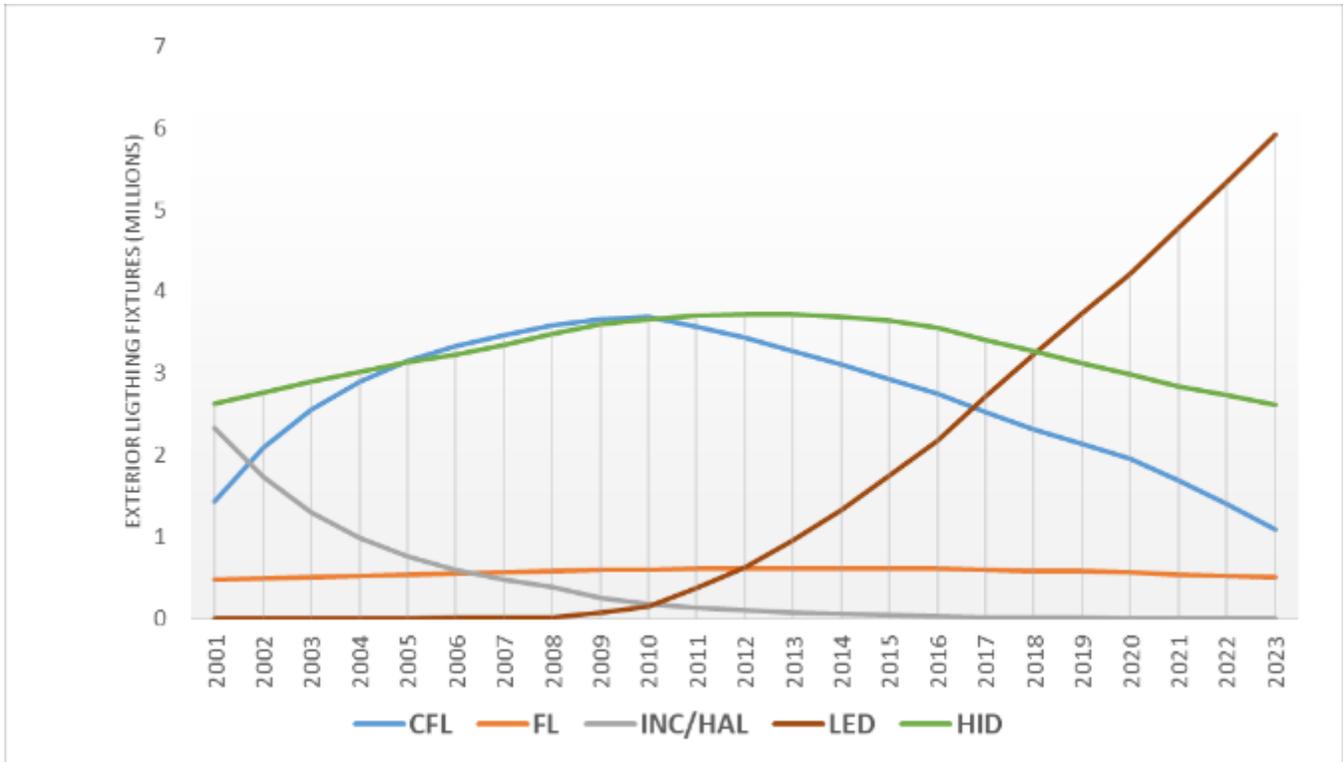


Figure 18 shows that LEDs have just surpassed HID technology to become the most prevalent technology. HID fixtures are slowly declining but persist in high volumes as many customers choose to maintain existing systems instead of conducting a retrofit. Fluorescent fixtures also persist in significant numbers, primarily for replacements in fuel canopies and in some wall mounted products. CFLs are rapidly declining as customers move to LEDs.

Table 38 shows the percent of installed exterior lighting products by technology, 2018 through 2023, using the values in Figure 17. The first set of rows includes LEDs and represents total installed products. The second set of rows excludes LEDs and is intended to better represent the fraction of technologies replaced through LED retrofits. TRC removed LEDs from the second set of rows, since most customers are unlikely to retrofit existing LEDs with new LEDs (since there is less energy savings, and they were installed relatively recently). There is a possibility that the initial wave of LEDs will burn out before 2023. However, LED fixtures installed in exterior applications have an approximately 12-year effective useful life.²⁹ Consequently, the LEDs that customers installed in the early years of market uptake (which ramped up significantly starting in 2012) should start failing around 2024 on average.

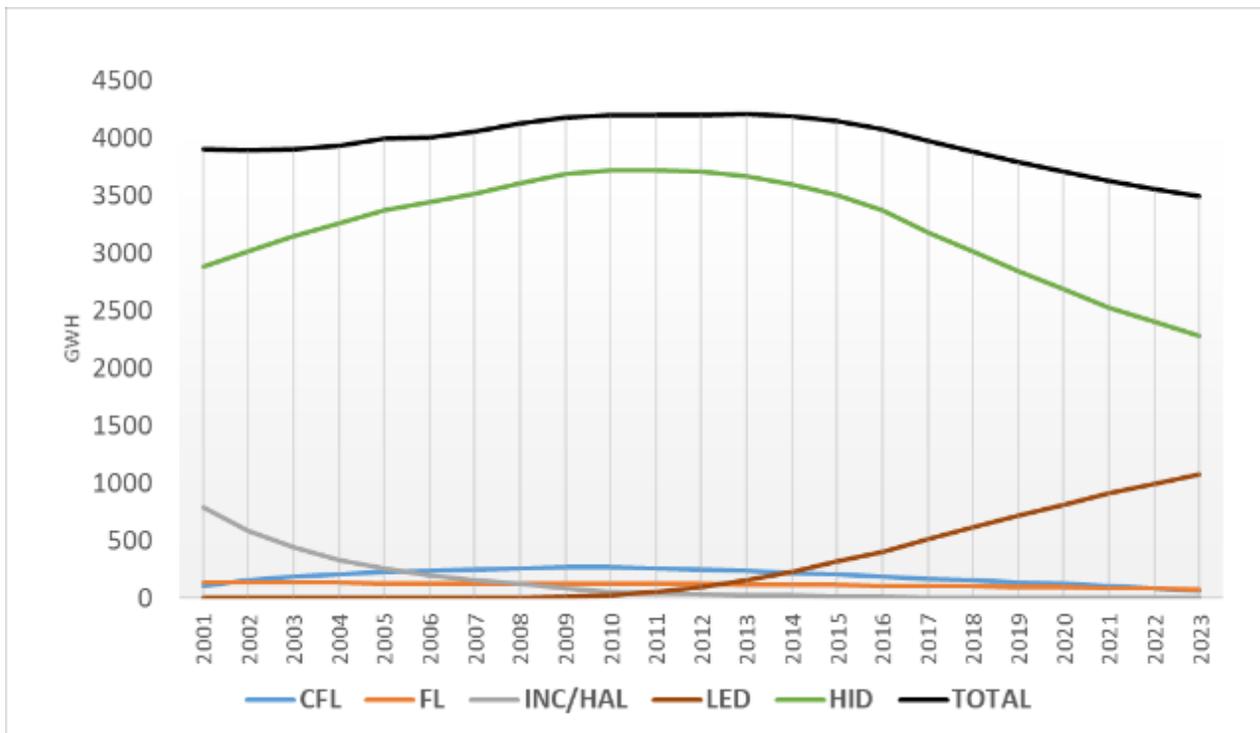
²⁹ DEER2016 assumes an LED fixture has an EUL of 50,000 hours and assumes 4,100 annual hours of operation for exterior spaces. $50,000 \text{ hrs} / 4,100 \text{ hrs/yr} = 12.2 \text{ years}$. Parking garage lighting runs continuously, but the model of installed fixtures does not include parking garage lighting.

Table 38: Estimated Percentage of Exterior Lighting Fixtures Installed, by Technology

Year	CFL	FL	INC/HAL	HPS	LPS	MH	MV	LED
Includes LEDs								
2018	25%	6%	0.1%	14%	0.4%	19%	1%	34%
2019	22%	6%	0.1%	13%	0.4%	18%	1%	39%
2020	20%	6%	0.0%	12%	0.4%	17%	1%	43%
2021	17%	5%	0.0%	11%	0.3%	16%	1%	48%
2022	14%	5%	0.0%	11%	0.3%	15%	1%	53%
2023	11%	5%	0.0%	10%	0.3%	15%	1%	58%
Renormalized Percentages (Excluding LEDs)								
2018	38%	9%	0.2%	21%	1%	30%	2%	
2019	36%	10%	0.1%	21%	1%	30%	2%	
2020	36%	10%	0.1%	22%	1%	31%	2%	
2021	33%	11%	0.0%	22%	1%	32%	2%	
2022	30%	11%	0.0%	23%	1%	33%	2%	
2023	26%	12%	0.0%	25%	1%	35%	2%	

Figure 19 shows estimates of electricity use by technology, for 2001 to 2023, with HID technologies grouped together. HID fixtures tend to be high wattage and high output, so the relatively high quantity of HID sources seen in Figure 18 lead to HID dominating electricity use through 2023. LED electricity use increases steadily due to their increasing penetration.

Figure 19: Estimated Electricity Use of Exterior Lighting Installed in California, by Technology



Because LEDs are approximately 50% more efficient than HID technologies and CFLs, and 20% more efficient than linear fluorescent technologies, and based on the current installed stock of these technologies, TRC estimates that exterior lighting electricity use could be reduced by approximately one-third if the entire stock of exterior lighting is converted to LEDs.

While TRC used the best data available, some inputs were not available in past studies or from the data collected here. In particular, TRC could not find a reliable value for the fraction of exterior lighting systems that are retrofitted, compared to maintained, each year. Consequently, TRC used our professional best judgment to estimate the percent of exterior lighting systems retrofitted each year, with a peak retrofit rate of 5% from 2016 to 2020 due to falling prices of LEDs. Different assumptions for retrofit rates would lead to different penetrations of technology and their electricity use. In addition, future exterior lighting retrofit rates will be affected by the size of IOU programs to support these projects. Overall, TRC estimates that the results of our replacement model are accurate to within approximately +/- 15%. The overall conclusions would remain the same: there is substantial energy savings potential from installed HID and fluorescent technologies.

4.6.2 Market Actor Survey Responses of Technologies Retrofitted

As part of our phone surveys, TRC asked manufacturer rep and maintenance contractors for their estimates of the technology of fixtures removed (i.e., incumbent technologies) in exterior lighting retrofit projects. Note that fixtures removed as gathered in the surveys are not the same as existing stock as estimated in our model, shown in Figure 17. Market actors are more likely to replace incumbent technologies than LEDs because there is more energy savings from replacing incumbent technologies. Table 39 shows results of the manufacturer rep responses.

Table 39: Replaced Technologies in Exterior Retrofits, as Reported by Manufacturer Reps

	Value	LED	MH	HPS	LPS	Lin. Fl	CFL	Other
Streetlight	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	10%	100%	95%	100%	20%	0%	8%
	Average	1%	31%	36%	19%	4%	0%	1%
	Weighted Ave.	2%	38%	25%	32%	3%	0%	1%
Pole Mount	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	20%	90%	95%	60%	10%	0%	8%
	Average	3%	39%	36%	23%	1%	0%	1%
	Weighted Ave.	4%	31%	26%	23%	0%	0%	1%
Wall Mount	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	80%	75%	50%	0%	50%	13%
	Average	0%	48%	24%	7%	0%	19%	2%
	Weighted Ave.	0%	40%	25%	12%	0%	21%	1%
Floodlight	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	100%	75%	50%	30%	20%	40%
	Average	0%	58%	19%	6%	4%	4%	8%
	Weighted Ave.	0%	43%	23%	11%	7%	1%	11%
Bollard	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	60%	99%	50%	0%	50%	0%
	Average	0%	40%	31%	6%	0%	20%	0%
	Weighted Ave.	0%	38%	28%	11%	0%	18%	0%
Fuel Canopy (4 Responses)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	100%	50%	30%	100%	0%	0%
	Average	0%	55%	13%	8%	25%	0%	0%
	Weighted Ave.	0%	31%	19%	12%	38%	0%	0%
Parking Garage	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	98%	30%	100%	100%	0%	1%
	Average	0%	46%	8%	13%	29%	0%	0%
	Weighted Ave.	0%	19%	9%	23%	41%	0%	0%

In summary, manufacturer reps reported that for their exterior retrofit projects:

- ◆ MH is the technology most often retrofitted for most product categories.
- ◆ HPS or LPS are secondary technologies retrofitted for most product categories.
- ◆ Linear fluorescents are a significant portion of fuel canopy and parking garage retrofits.
- ◆ CFLs are often retrofitted in wall mounted and bollard applications.

Table 39 does not include results for pool lighting or street sign lighting, because TRC did not survey enough manufacturer reps that sell these products to quantitatively analyze results. One manufacturer rep sells pool lighting and reported that pool light retrofits are approximately 50% metal halide and 50% incandescent /

halogen. Two manufacturer reps surveyed sell street sign lighting. Both reported that approximately half of these retrofits replace metal halides; one rep reported the remainder replace HPS, while the other rep reported the remainder replace linear fluorescents.

Maintenance contractors provided a mix of quantitative and qualitative response to the question of the fixture technology that they retrofit for each product category. (Some contractors provided responses qualitatively because of survey time constraints.) TRC combined responses across maintenance contractors and provides qualitative results in Table 40.

Table 40: Replaced Technologies in Exterior Retrofits, as Reported by Maintenance Contractors

Product Category	Primary technologies retrofitted
Streetlight	MH and LPS
Pole Mount	Primarily MH, with some HPS and fluorescent
Wall Mount	Primarily MH, with some HPS and fluorescent, and a small amount of incandescent
Floodlight	Primarily MH, followed by HPS, and a small amount of fluorescent and incandescent
Bollard	Primarily MH or HPS, and a small amount of fluorescent and incandescent
Parking Garage	Primarily MH and linear fluorescent, with some HPS

Only two maintenance contractors provided a response for fuel canopies, and both reported these are typically LPS retrofits. None of the maintenance contractors provided a response for pool lighting or street sign lighting.

Manufacturer rep responses agreed with the maintenance contractor survey responses, with both indicating that MH was the most frequently retrofitted technology, HPS second for several categories, and fluorescent technologies (either linear fluorescent or CFL) as significant for wall mounted and parking garage lighting.

4.6.3 Comparison of Results to Literature Review Findings of Installed Exterior Technologies

TRC reviewed the following literature for installed fixtures by technology:

1. Commercial Building Stock Assessment (NEEA 2016) – This report provides a distribution for outdoor lighting power based on technology and product categories, with data collected in 2014.
2. California Commercial Saturation Survey (Itron 2014) – This report provides an estimate of all baseline equipment in the commercial buildings in California, with data collected 2009 to 2012. For outdoor lighting, the report includes distribution based on technology for all outdoor lamps, not for each product category within outdoor lighting.
3. US Lighting Market Characterizations (DOE 2017a) – This report provides an estimate of installed stock for all general illumination lighting products in the U.S., with data collected 2009 to 2017. The relevant outdoor applications from this report include streetlighting/roadways, parking (lots and garages), and commercial and industrial lighting.

Table 41 summarizes the product categories covered in each study, and how the results are presented. As shown, each study presented results differently.

Table 41: Product Categories Covered in Published Studies of Installed Lighting

Product Category	Commercial Building Stock Assessment (NEEA 2016)	California Commercial Saturation Study (CSS: Itron 2014)	US Lighting Market Characterizations (DOE 2017a)
Streetlight	No	No	Yes
Pole Mount	Yes	Yes	Yes
Wall Mount	Yes	Yes	Yes
Parking Garage	Yes	Yes	Yes
Comment	Provides power (but not fixture) estimates for each product category	Provides overall number of fixtures for exterior lighting. Does not break out results by product category	Provides number of fixtures for street-lighting, parking (combines parking lot and parking garages), and wall mounted

Section 6.7 in the appendix provides results for relevant product categories in each study. TRC summarized the findings from each study as part of Table 42, which compares our results with findings of the published studies. Note that this figure uses merged cells that span across multiple product categories where data sources provide results combined across multiple product categories. For example, DOE (2017a) presents data for parking garages and lots combined, so Table 42 shows results as spanning the parking garage and pole-mounted categories. For the CSS study, Table 42 shows results from customers that did not participate in efficiency programs, because TRC believes these are more reflective of the broader market; values for program participants were similar for most technologies. For clarity, Table 42 does not show values for technologies that are less than 5%.

Table 42: Comparison of Installed Stock and Replaced Technologies

Product Category	TRC Estimates (Collected 2018)		Past Studies		
	TRC Model of 2018 Existing Stock	Manufacturer Rep Survey Responses of Technologies Retrofitted	CSS of Existing Lamps (Data collected 2011-13)	NEEA CBSA Existing Stock (Data Collected 2014), % as Power consumption	DOE Lighting Market Char. Existing Stock (Data Collected 2009-2017)
Streetlight	Not included	MH: 38% HPS: 25% LPS: 32%	Not included	Not included	HPS: 74% LED: 19%
Parking Garage	Not included	MH: 19% HPS: 9% LPS: 23% Lin. Fluor: 41%	HID (includes MH, HPS, LPS): 17% Lin. Fluorescent: 20% CFL: 46% Inc/Halogen: 16%	HID (includes MH, HPS, LPS): 42% Lin. Fluor: 53%	Parking garages and lots (combined): MH: 32% HPS: 17% LED: 28% Other: 11%
Pole Mount	MH: 21% HPS: 16% Lin. Fluor: 7% CFL: 27% LED: 27%	MH: 31% HPS: 26% LPS: 23%		Parking lots: HID (includes MH, HPS, LPS): 93%	Combined with other categories
Wall Mount		MH: 40% HPS: 25% LPS: 12% CFL: 21%		Walkway/area lighting: HID: 68% CFL: 12% Incandescent: 12%	
Floodlight		MH: 43% HPS: 23% LPS: 11% Lin. Fluor: 7%		Combined with other categories	
Bollard		MH: 38% HPS: 28% LPS: 11% CFL: 18%			

After accounting for differences in product categories, the different sources indicate similar findings in terms of the dominant technologies in the existing stock.

- ◆ For streetlighting:
 - The DOE Lighting Market Characterization study estimates that 74% of existing stock is HPS. Manufacturer reps estimated that 25% of streetlighting retrofits replace HPS, and the remainder replace MH and LPS. TRC does not know why there is a discrepancy in results. However, both data sources indicate that some type of HID technologies are the primary technologies replaced.
 - The DOE study estimates that existing stock is 19% LEDs. Manufacturer reps reported almost no LED-to-LED retrofits. The discrepancy is likely because the DOE report shows *installed* stock, while manufacturer reps reported the technologies most likely *replaced*.
- ◆ For parking garage lighting, the NEEA CBSA indicates that 42% of existing stock is HID, and 41% are linear fluorescent. Manufacturer reps estimated that 51% of retrofits are HID (combining results for MH, HPS, and LPS) and 41% are linear fluorescent. These results align well.

The comparison is difficult for other product categories, because of differences in classification. However, comparing TRC's model of the installed stock with manufacturer rep responses of lighting retrofitted:

- ◆ Both show a high prevalence of HID technologies, primarily MH and HPS.
- ◆ TRC's replacement model shows a high prevalence of CFLs installed. Manufacturer reps reported CFLs are a significant (but not dominant) technology retrofitted in wall mounted applications. The discrepancy in results may be because these data sources show different estimates: TRC's model shows *installed* stock, while manufacturer reps reported technologies that are *replaced*. (Manufacturer reps are not active enough in maintenance projects to provide a reliable estimate of the installed stock.) CFLs may be less preferentially retrofitted compared with other technologies.

As part of calibrating our model, TRC compared our results with the CSS data. Because CSS data collection occurred 2011-2013, TRC compared results for our model of installed stock for 2011 – the middle year of CSS data collection, with CSS results:

- ◆ For 2012, TRC's model estimates that LED penetration was 2%, which aligns with the CSS finding: 2% in program and non-program participants. The low penetration of LEDs in CSS validates TRC's assumption in our model that the significant LED ramp up began after 2012.
- ◆ Both show a high prevalence of CFLs. For 2012, TRC's model estimates that CFLs comprised 41% of installed stock, which aligns well with the CSS finding that CFLs comprised 46%.
- ◆ TRC's model for 2012 estimates that incandescent and halogen lamps comprised 1%, while CSS found they comprised 16%. The difference was lower for the program participants in CSS data, which showed only 6% of installed exterior stock was incandescent and halogens. The remaining difference with TRC's replacement model may be because of differences in building types in the data sets.
- ◆ TRC's lamp replacement model shows a higher fraction of HIDs (44% for 2012) compared with CSS (17%), which may indicate differences in building types in the data sets. As shown in Table 42, the NEEA CBSA and DOE Market Characterization confirm TRC's results that the majority of installed exterior lighting stock is HID.
- ◆ CSS shows a higher penetration of linear fluorescents (20%) compared with the TRC model (7%) because CSS includes parking garages, which was not included in TRC's model.

In general, TRC believes that our model of installed fixtures is the best estimate for exterior lighting existing stock in California for 2018 through 2023 for the products covered in the model: pole-mounted, flood and spot lighting, wall mounted, fuel canopy fixtures, and bollards.

4.7 Lamp Replacement (Maintenance) Market and Barriers to Retrofits

While the focus of this study was the new construction and retrofit markets, TRC collected some information on the replacement market.

4.7.1 Barriers to Retrofits

TRC asked manufacturer reps and maintenance contractors why some customers choose to maintain the existing system by replacing failed lamps, as opposed to conducting a retrofit. TRC framed the question as open-ended. Because of survey time constraints, and because this was one of the last questions in the survey, the surveyor skipped this question in some surveys. Of the 15 market actors that provided a response, 14 cited cost as the primary barrier. The results are shown below in Table 43.

Table 43: Number of Market Actors that Cited Cost as Barrier to Retrofit

Market Actor	Number of Respondents That Cited Cost as Barrier (%)
Manufacturer Reps (n=8)	8 (100%)
Maintenance Contractors (n=7)	6 (86%)
Total (n=15)	14 (93%)

Some indicated that part of the problem is a lack of customer understanding of the true financial benefit of the retrofit. Manufacturer rep responses included:

- ◆ “[Customers] don’t want to spend the money. If it’s not required by Title-24 to upgrade, they will stick with the basic and replace ballasts and lamps to their hearts content.”
- ◆ “They’re looking at first cost only. They have their maintenance budget that doesn't allow them to project beyond that. It’s myopic.”
- ◆ “Because it's an investment - the labor and cost of the product. But they don't see the true cost. At the end of the day, it's paid for itself because [energy] consumption went down.”
- ◆ “It all comes down to cost.”

Maintenance contractor responses included:

- ◆ “Price. Utilities are giving lower rebates and thus customers are maintaining more metal halides because rebates do not cover the gap for the better technology.”
- ◆ “Budgets. These are property managers. Even if it’s \$100 more for LEDs, they’d rather just keep the same old.”
- ◆ “It’s mainly a financial issue. Small customers are more likely to do replacements instead of retrofits. The more organized the customer – the ones with many properties – are more likely to do retrofits.”
- ◆ “Budget. It’s all just maintenance unless they can afford a retrofit.”

TRC also asked market actors what technology was generally used for replacements. All respondents reported that in the majority of cases, they will replace lamps with the same technology as what they removed.

4.7.2 Size of Replacement Market

While it is difficult to estimate the size of the replacement market, there are several indicators that the replacement market – i.e., maintenance of an existing system by replacing failed lamps and fixtures – is a large fraction of the overall market.

TRC's model of installed fixtures indicates that the majority of fixtures will continue to be non-LED technologies through 2023 (see Figure 17). In addition, national shipment data from the National Electrical Manufacturers Association (NEMA) indicate that a large portion of shipments continue to be incumbent technologies. Figure 44 in the appendix presents NEMA sales indices for linear lamps and shows that linear fluorescent lamp sales decreased approximately 50% since 2011. Figure 45 in the appendix shows that tubular LEDs (TLEDs) comprised just under 25% of total linear products in 2017 and that T8s comprise the majority of linear products (followed by T12s and T5s). Combining these results, LEDs contribute to (but are not the sole reason for) linear fluorescent lamp sales decline, and T8s continue to dominate linear lamps. As shown in Figure 46 in the appendix, NEMA lamp indices show that HID lamp sales have dropped by approximately 60% since 2011. NEMA does not provide indices for LED lamps that are comparable to HIDs, but the increase in LEDs is likely a major contributor to HID sales reductions. However, HID lamps continue to be sold in large quantities.

4.7.3 Example of Base Case Measure Cost and IMC if Maintenance Incorporated

The incremental measure cost (IMC) calculation in current IOU work papers for fixtures assumes that the base case is a standard practice fixture. Based on our findings, the standard practice fixture would be an LED, with an efficacy that depends on the product category and output. However, that IMC calculation does not accurately model a customer's decision. The typical choice facing the customer is to maintain the existing system by replacing failed lamps with the old technology, or to conduct a retrofit with LED fixtures. Consequently, the IMC for an exterior lighting retrofit project should assume a blend of lamp replacements (to reflect the maintenance market) and fixture replacements (since some fraction of the market will conduct a retrofit).

To investigate the impact of adjusting the IMC calculation to reflect a blend of lamp replacements and fixture retrofits, this section provides a simple example for pole-mounted fixtures in the high output range, such as parking lot fixtures.

IMC assuming blend of maintenance and standard practice retrofit:

Based on TRC's industry experience, HID lamps are typically \$25 to \$50, and HID ballasts are typically \$100 to \$150 and must be replaced approximately every third lamp replacement. In the exterior lighting replacement model, TRC assumed that exterior lighting retrofit rates will peak at 5% per year. The value of 5% also aligns with the DOE (2014) assumption for national lighting retrofit rates. Thus, TRC assumed that:

- ◆ 95% of the market will be maintenance, lamp replacements will cost approximately \$50, and ballast replacements will cost approximately \$50 (based on \$150/3, since one-third of lamps will need a new ballast), for a total equipment cost of \$100.
- ◆ 5% of the market will be retrofits, with an equipment cost of \$1,000 for an LED fixture, based on our standard practice pricing findings shown in Table 26.

Thus, for a lamp/fixture blend, TRC estimates a base case cost of $95\% \times \$100 + 5\% \times \$1,000 = \$145$. For the IMC calculation, the measure cost would be a DLC Premium fixture. Based on this study's findings, the mean cost for a DLC Premium high-output pole-mounted fixture is \$958 (See Table 20). Thus, under these assumptions:

$$IMC = \text{measure cost} - \text{base cost}_{\text{blend of maintenance and standard practice for retrofit}} = \$958 - \$145 = \$813$$

IMC assuming standard practice is retrofit (using current work paper methodology):

In comparison, the current IMC methodology in work papers assumes that the base measure is an LED fixture. Consequently, = under the current assumptions:

$$IMC = \text{measure cost} - \text{base cost}_{\text{standard practice for retrofit}} = \$958 - \$1,000 = -\$42$$

Comparison³⁰:

Under the current IMC methodology in work papers, the IMC is negative. A low or negative IMC prevents the IOUs from providing incentives for many exterior lighting fixtures. Under the proposed IMC methodology, the IMC is much higher (approximately \$800) and better reflects the different cost options facing most customers.

This example is for illustrative purposes, to provide a ballpark estimate of how the IMC would change if maintenance is incorporated. One of the inputs that is unknown is the percent of the market that conducts an exterior lighting retrofit each year. TRC assumed a retrofit rate of 5% based on industry judgement; the exterior lighting retrofit rate is unlikely to be higher than 10%. Even at 10%, the base case measure cost would be \$190³¹, and the IMC would be \$768³², so would still be approximately \$800.

³⁰ These estimates do not include labor since both lamp replacements and fixture retrofits require labor. Labor would be similar if not lower for some lamp replacements since fixture retrofits are more extensive and less likely to be done by in-house maintenance staff.

³¹ $90\% \times \$100 + 10\% \times \$1,000 = \$190$

³² $\$958 - \$190 = \$768$

5. CONCLUSIONS

On behalf of the California IOUs, TRC conducted a standard practice study of exterior fixtures to support work papers for exterior lighting fixtures and retrofit kids. The CPUC had directed the IOUs to conduct a standard practice study to inform the first baseline for new construction and replace-one-burnt out projects, and the second baseline for early retirement projects. As our primary method of data collection, TRC surveyed manufacturers, manufacturer reps, and maintenance contractors; collected product efficacy and pricing from manufacturer rep quotes and from collecting data from online retailers; developed a mathematical model of the installed stock of exterior fixtures; and estimated projections of efficacy and pricing using literature review values of efficacy and pricing rates of change.

5.1 Standard Practice for Exterior Lighting Sales and Projections

LEDs dominate current exterior fixture sales in California. All market actors surveyed reported that LEDs comprise the majority of their exterior lighting fixture sales and installations in NC and retrofit projects. **TRC's best point estimate is that LEDs comprise 94% of current exterior fixture sales for NC and retrofits.** TRC found almost no difference in LED penetration between NC and retrofits, and generally little difference in LED penetration among the product categories. According to Resolution E4952, CPUC will assume 100% LEDs for all exterior lighting categories beginning January 1, 2019³³. For the product categories in this study, our findings indicate this is a reasonable assumption.

Market actors surveyed predicted that by 2020 and 2023, their fraction of exterior sales for NC and retrofits that will be LEDs will be 98% and 99% respectively. These findings are significantly higher penetrations of LEDs than what DOE predicted nationally: 75% penetration of LEDs for outdoor lighting sales by 2020 and 97% by 2025 (DOE 2014). The discrepancy may be due to differences between California and the rest of the U.S. due to code, utility programs, or customer business practices; because we collected data more recently than DOE; due to differences in methodology; or for other reasons.

Based on the average weighted response across market actors, **DLC Standard fixtures are most the prevalent among current exterior fixture sales and installations**, followed by DLC Premium, and finally non-DLC listed. While there was some difference in the percentage splits by product category, all product categories followed this overall trend. **TRC's best point estimate is 58% DLC Standard, 31% DLC Premium, and 10% not DLC listed across all exterior fixtures.** All types of market actors reported that DLC-listed fixtures (either DLC Premium or DLC Standard) are at least 85% of exterior fixture sales, but there was less consistency in the split between DLC Premium and DLC Standard among market actors.

TRC collected efficacy and pricing data for a range of products using pricing quotes from manufacturer reps and information from on-line retailers. The data includes non-DLC, DLC Standard, and DLC Premium fixtures. While there was considerable variation in efficacy for many non-DLC listed products, their average efficacy is lower than the average efficacy for DLC Standard products in the same product category. By applying weights that assume sales are 58% DLC Standard, 31% DLC Premium, and 10% not DLC listed, TRC developed best point estimates for each product category, as shown in Table 44.

³³ Draft Resolution E4952 <http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M225/K049/225049353.PDF>

Table 44: Standard Practice Efficacy Estimate by Product Category

Lumen Output	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low <5k	109	109	103	106	54	117	108
Mid 5k-10k	107	110	111	113	N/A	115	111
High 10k-30k	113	115	117	114	N/A	117	116
Very High >30k	133	116	N/A	111	N/A	N/A	N/A

According to Resolution E4952, CPUC will assume 100 Lm/W for all exterior product categories beginning January 1, 2019. This appears to be a reasonable estimate for all product categories except bollards. Based on projections for the rate of efficacy increase from DOE (2014), TRC assumed that exterior fixture efficacy will improve by 3.3% annually in the next five years, and projected best point estimates for each product category through 2023.

TRC found no consistent trends in pricing other than that the price will increase as the light output increases. Prices ranged considerably within the same group of products, and there was no clear trend in pricing based on DLC-designation. Using the same approach for LED pricing in which we applied weights based on sales by DLC-designation (58% DLC Standard, 31% DLC Premium, and 10% non-DLC), TRC provided best point estimates for pricing for each product category. TRC found three studies with price projections: Freedonia (2018) estimated an annual price *increase* of 1.4%, while DOE (2014) estimated a price *decrease* of approximately 6.5% per year, and Navigant (2018) estimated a price decrease that varied by year (11% decrease for 2018 to 2019 and declining to 7% decrease for 2022 to 2023). Based on a price per kilolumen, TRC’s pricing – collected Q3 2018 – was lower than the prices found by Navigant (2018) collected Q4 2016 through Q2 2017. Consequently, TRC expects prices to decrease. For our price projections, we averaged the values from DOE (2014) and Navigant (2018), and we included an adjustment for inflation, to assume prices will decrease each year, ranging from a decrease of 8% (for 2018 to 2019) to a decrease of 5% (for 2022 to 2023). Both current and projected prices have a high level of uncertainty, given the large variation in current prices and the disagreement in the literature regarding future product pricing.

5.2 Installed Exterior Lighting

TRC estimated the installed(existing) stock of exterior lighting products (fixtures and lamps) from 2001 through 2023 that included pole-mounted, wall mounted, flood and spot lighting, bollards, and fuel canopy fixtures. TRC used inputs from market actor surveys for some key inputs and validated the model results against a study of installed stock (CSS – Itron 2014) for the year 2012. As shown in Table 45, the model predicts that LEDs are currently overtaking HID technologies as the largest fraction of the current installed stock. **While the model predicts that LEDs are slowly replacing incumbent technologies, HID technologies will dominate electricity use through 2023.** The cumulative electricity use of exterior lighting in the mathematical model is approximately 4.0 TWh. California’s exterior lighting electricity use could be reduced by approximately one-third – representing 1.3 TWh of savings potential – if the entire existing stock of exterior lighting was converted to LEDs.

Table 45: Estimate of Installed Exterior Lighting Products and their Electricity Use in California in 2018 and 2023

Technology	HID	LED	CFL	Linear Fluorescent
Installed Stock of Lighting Products, 2018 (%)	35%	34%	25%	6%
Installed Stock of Lighting Products, 2023 (%)	26%	58%	11%	5%
Electricity Use of Installed Stock, 2018 (%)	77%	16%	4%	3%
Electricity Use of Installed Stock, 2023 (%)	65%	31%	2%	2%

Manufacturers and maintenance contractors reported that HIDs are retrofitted most often³⁴ for almost all product categories, which aligns with the findings of our mathematical model. Market actors reported that linear fluorescents are frequently retrofitted in fuel canopy and parking garage projects, and CFLs are often retrofitted in wall mounted and bollard applications.

5.3 The Maintenance Market and Barriers to Retrofits

Many data sources indicate that commercial customers choose to maintain their existing exterior lighting system – i.e., replace failed lamps, ballasts, and fixtures, instead of retrofit the entire system. NEMA lamp indices show that HID lamp sales have dropped significantly but continue to be sold in large quantities, and that fluorescent technologies (primarily T8s, followed by T12s and T5s) comprise over 75% of linear lamps, with TLEDs comprising just under 25%. TRC’s surveys with manufacturer reps and maintenance contractors also found that many customers choose to maintain the existing system instead of pursuing a retrofit.

Manufacturer reps and maintenance contractors reported that **the primary reason why customers choose to maintain – instead of retrofit - their exterior lighting systems is cost**. These market actors reported that most customers maintain the system with the same technology if possible (i.e., replace like with like). Some of them indicated a need for educating customers so they understand the true financial benefit of an LED retrofit.

5.4 Recommendations

The CPUC should revisit the approach of the IMC calculation for retrofit fixture projects, so it reflects a mix of fixture and lamp replacements to better model a customer’s decision. The IMC calculation in current IOU work papers for fixtures assumes that the base case is a standard practice fixture. Based on our findings, a standard practice fixture would be an LED, with an efficacy that depends on the product category and output. However, that IMC calculation does not reflect a customer’s decisions. The typical choice facing the customer is to maintain the existing system by replacing failed lamps with the old technology, or to conduct a retrofit with LED fixtures. TRC calculated an example to investigate how the IMC would change if the base case assumed a blend of maintenance (cost for incumbent technology lamp replacements) and retrofits (cost for LED fixtures). For high-output pole-mounted fixtures, a base case that assumes a blend of HID lamps and LED fixtures has an estimated cost of \$145, which would yield an IMC of \$813. The current IMC methodology in work papers assumes that the base measure is a standard practice fixture – found here to be an LED fixture with an average price of \$1,000, which yields a negative IMC: -\$42. The negative IMC is one reason that IOUs are not

³⁴ Within the HID category, these market actors reported metal halides are retrofitted most often, followed by HPS and then LPS.

incentivizing many exterior lighting product categories. Adjusting the IMC to assume that the base case is a blend of incumbent technology lamps and LED fixtures would better reflect a customer's decision and significantly increase IMC results.

The CPUC or IOUs should conduct a follow-up IMC study to further explore pricing of exterior LED fixtures, and how these are likely to change in the future. This study found significant variation in pricing among LED fixtures, but it was beyond the scope of this study to identify why certain product types carried higher prices. In addition, the price projections in this study have high uncertainty, since even the direction of LED fixture prices (up or down) was uncertain in the literature. TRC recommends that an IMC study explore:

1. Current pricing trends, including investigating why some products carry higher prices than others, and
2. The impact of different forces on future pricing, including the declining costs of LED technology, additional costs due to new LED features and how to account for differences in features among fixtures, and the impacts of tariffs.

In addition, TRC recommends additional research to determine exterior lighting retrofit rates. The result could be used as an input in the calculation of a blended lamp/fixture base case in the IMC and improve the accuracy of models of installed exterior lighting stock.

In conclusion, while TRC found that LEDs are standard practice, TRC recommends that IOU intervention continue for existing exterior lighting projects. IOU incentives and education will help customers overcome the first-cost barrier of performing an LED retrofit, rather than choosing to maintain the existing system. This intervention would help accelerate the shift of existing stock from HIDs and fluorescents to LEDs, generating significant energy savings.

6. REFERENCES

- DOE, “Energy Savings Forecast of Solid-State Lighting in General Illumination Applications”, 2014. <https://www.energy.gov/eere/ssl/downloads/energy-savings-forecast-solid-state-lighting-general-illumination-applications>
- DOE, “Adoption of Light-Emitting Diodes in Common Lighting Applications”, 2017. Cited here as DOE 2017a. https://www.energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf
- DOE, “Solid State Lighting 2017 Suggested Research Topics”, 2017. Cited here as DOE 2017b. https://www.energy.gov/sites/prod/files/2017/09/f37/ssl_suggested-research-topics_sep2017.pdf
- Itron. “Commercial Saturation Survey”, 2014. http://www.calmac.org/publications/California_Commercial_Saturation_Study_Report_Finalv2.pdf
- Navigant. “California LED Pricing Analysis”, 2018. http://calmac.org/publications/LED_Pricing_Analysis_Report_-_Revised_1.19.2018_FinalES.pdf
- The Freedonia Group. “General Purpose Lighting Fixtures in the US, 14th Edition”, 2018. Available for purchase as described here: <https://www.freedoniagroup.com/industry-study/general-purpose-lighting-fixtures-in-the-us-by-product-market-and-region-14th-edition-3637.htm>
- NEEA. “Commercial Building Stock Assessment: Final Report (CBSA)”, 2016. <https://neea.org/resources/2014-cbsa-final-report>

7. APPENDIX

7.1 Methodology for Identifying Lighting Market Actor Contacts

TRC used a combination of internet searches – the main source of contacts for manufacturer reps and maintenance contractors, and TRC and IOU existing contacts – the main source of contacts for manufacturers – to develop a population of contacts.

7.1.1 Manufacturers

For major lighting manufacturers (Acuity, Cooper, Philips, Hubbell, and General Electric [GE]), TRC used existing contact information from both TRC and IOU employees. TRC used personal contacts because there are only a small group of major manufacturers, and personal contacts are more likely to respond to survey requests.

7.1.2 Manufacturer Reps

TRC visited websites for major outdoor lighting manufacturers and used site links to navigate to sales pages. TRC first targeted the five largest lighting manufacturers (Acuity, Cooper, Philips, Hubbell, and GE) to identify sales representatives in major metropolitan areas such as Los Angeles, San Francisco, and San Diego. Next, TRC searched for other companies known to be popular for exterior lighting (Cree, RAB, Deco, and Maxlite). TRC followed a similar strategy for these companies, identifying manufacturer reps for major areas.

When possible, TRC identified individual contacts at each representative company. Additionally, both utility and non-utility (specification) representatives were selected if available. In some cases, TRC identified multiple unique contacts at the same company office with the same role, based on their title. Because TRC expected that many manufacturer reps will decline the survey request, TRC captured all unique contacts, but contacted one person at each company office with the same title at a time; if they declined the survey request or did not respond after multiple attempts, TRC moved to the next person in the office with that title.

7.1.3 Maintenance Contractors

TRC used search terms such as “Exterior Lighting Maintenance Contractor” or “Lighting Maintenance Contractor”, along with regional terms such as “Southern California” or “Bay Area California” to find a list of maintenance contractors for different regions in California. TRC then visited the sites of the contractors to confirm the following before adding the company information to the contact list:

- ◆ The company conducts maintenance work in California.
- ◆ The company does exterior lighting maintenance work, not just interior lighting or other electrical maintenance.

TRC recorded regions served, and the product categories served by reviewing lists of projects, photos, and maps on the company website.

TRC also identified a mix of maintenance contractors representing different areas of California and customer segments (large/small, commercial/public).

7.2 Manufacturer Survey Responses

This section provides results of the manufacturer surveys.

7.2.1 Sales by Technology

TRC asked the respondents which of the nine product categories they manufacture. Table 46 presents results.

Table 46: Number of Manufacturers Surveyed that Produce each Product Category

Product Categories								
Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Pool	Street Sign
6	6	6	5	4	5	5	1	2

Three out of the six respondents manufacture 100% LED luminaires for these product categories. The three largest manufacturers that TRC surveyed continue to manufacture other technologies, primarily MH and HPS. Table 46 presents the results. Only two of the six respondents had insight to whether the end use of their products was new construction or retrofits.

Table 47: Manufacturer Sales by Technology

Technology							
	LED	MH	HPS	LPS	Linear FL	CFL	Other
Minimum	85%	0%	0%	0%	0%	0%	0%
Maximum	100%	10%	7%	1%	1%	1%	0%
Average	95%	2%	2%	0%	0%	0%	0%
Weighted Average	94%	2%	3%	0%	0%	0%	0%

TRC asked for percent of LED sales based on product category. Of the three respondents who manufacture non-LED products, two manufacture 100% LED for all product categories except streetlighting for one and parking garage lighting for the other. One respondent manufactures non-LED products in every category. Table 48 presents the results.

Table 48: Manufacturer Sales by Technology, by Product Category

Product Categories									
	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Pool	Street Sign
Minimum	70%	98%	58%	58%	70%	60%	85%	50%	65%
Maximum	100%	100%	100%	100%	100%	100%	100%	50%	100%
Average	94%	100%	93%	92%	93%	92%	95%	50%	88%
Weighted	81%	99%	86%	86%	83%	87%	97%	50%	65%

7.2.2 DLC designation and Efficacy for LED sales

TRC asked manufacturer reps for an estimate of their LED sales by DLC designation. All respondents manufacture significantly more products that are DLC listed than are not. All but one responded that they manufacture significantly more DLC Standard products than DLC Premium. One responded that they produce as much standard products as they do premium. One respondent indicated that although 40% of their products are currently premium, when rebates are in effect, they manufacture upwards of 70% premium products. Table 49 presents the results.

Table 49: Manufacturer Sales by DLC Designation: Overall for Exterior Fixtures

	DLC Rating			
	Premium	Standard	Listed	Non-DLC
Minimum	5%	45%	80%	2%
Maximum	45%	88%	98%	20%
Average	24%	68%	92%	9%
Weighted Average	23%	70%	93%	7%

Next, TRC asked for the fraction of sales by LED designation for each product category, with the option to respond with the percent that are DLC listed (combined across DLC Standard and DLC Premium) if needed. One respondent was not able to provide efficacy or DLC designation by category type. Two respondents provided efficacy data, and the remaining three opted for the combined DLC designation option. Table 50 provides the results.

Table 50: Manufacturer Sales by DLC Designation by Product Category

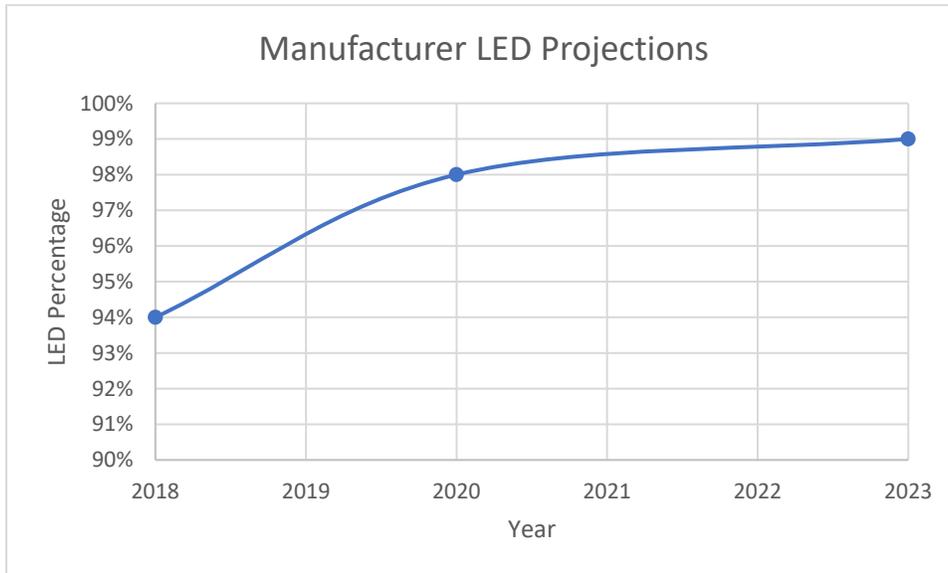
Product Category		DLC Designation			
		DLC Premium	DLC Standard	Listed	Not DLC Listed
Streetlight	Minimum	0%	50%	90%	0%
	Maximum	40%	100%	100%	10%
	Average	18%	79%	97%	4%
	Weighted Average	18%	78%	97%	3%
Pole Mount	Minimum	5%	0%	85%	0%
	Maximum	100%	91%	100%	15%
	Average	38%	55%	93%	7%
	Weighted Average	28%	65%	93%	7%
Wall Mount	Minimum	0%	50%	70%	0%
	Maximum	20%	100%	100%	30%
	Average	11%	82%	93%	9%
	Weighted Average	11%	81%	92%	8%
Floodlight	Minimum	0%	13%	13%	0%
	Maximum	45%	91%	100%	88%
	Average	22%	51%	73%	27%
	Weighted Average	24%	57%	81%	19%
Bollard	Minimum	0%	20%	20%	0%
	Maximum	25%	100%	100%	80%
	Average	8%	59%	67%	33%
	Weighted Average	8%	58%	65%	35%
Fuel Canopy	Minimum	0%	1%	80%	0%
	Maximum	99%	91%	100%	20%
	Average	54%	42%	95%	5%
	Weighted Average	48%	47%	95%	5%
Parking Garage	Minimum	2%	8%	10%	0%
	Maximum	50%	91%	100%	90%
	Average	15%	52%	68%	32%
	Weighted Average	15%	50%	65%	35%

TRC asked the respondents if they manufacture products with DLC qualifying efficacies that they do not list and why. Two respondents from large manufacturers said that if a product qualifies, they list it. They each indicated that they maintain product lines that do not qualify for more recent DLC requirements. There is still a demand for non-DLC products from customers who wish to match previous aesthetics. Another manufacturer said there is still a demand for less expensive products, especially if the client is not interested in rebates.

7.2.3 Projections of LED Penetration

TRC asked the three respondents currently manufacturing non-LED products for their projection of their LED products in the next two and five years. Of the three respondents who currently manufacture non-LED products, in five years, two projected they will be manufacturing 100% LED and the other projected 98%. TRC asked manufacturers who currently manufacture 100% LED for their projections of LED penetration in exterior fixtures. Two projected 100% LED in five years and one projected 98%. One respondent projected that for replacements (not new construction or retrofit) they will continue to manufacture other technologies passed the five years. The respondent specifically called out HPS as a technology they plan to continue at some level, stating that without a compelling reason, customers will maintain their HPS installation because they are relatively efficient. The same respondent noted that there is pressure on the market to phase out fluorescents in the next five years. Figure 20 shows the projected LED sales for the next five years.

Figure 20: Manufacturer 5-Year LED Projection



TRC asked for LED projection by product category. One respondent predicted streetlighting to shift to 100% LED earlier than other categories. A respondent who manufactures 100% LEDs but does not currently manufacture pool and streetlighting reported that they will be entering those markets with LED products. A respondent from a large manufacturer estimated that bollards, pool lighting, and streetlighting will lag in LED adoption. One respondent said that linear fluorescents for parking garage applications are popular and could maintain their popularity in California’s warm climate. In general, TRC found very consistent responses that LED penetration is high and will increase to approach 100% in the next few years.

7.2.4 Existing Products

TRC asked manufacturers what products were being replaced by their products. Only two manufacturers could estimate the technology being replaced in retrofits and renovation. They estimated that MH and HPS are most likely being removed. One respondent indicated that Night Sky observatories use LPS, but LED products are slowly becoming available for that application.

7.3 Manufacturer Rep Survey Responses

7.3.1 Sales by Technology

TRC asked the respondents which of the nine product categories they sell: streetlighting, pole-mounted, wall mounted, flood & spotlighting, bollards, fuel canopies, parking garage, pool lighting, and street sign lighting. Table 51 presents results.

Table 51: Number of Manufacturer Reps Surveyed that Sell each Product Category

Product Categories								
Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Pool	Street Sign
11	11	11	11	11	7	11	6	3

Next, TRC asked for the overall breakdown of sales by the following technologies: LED, MH, HPS, LPS, linear fluorescent, CFL, and other. TRC weighed all responses based on the size of the company and region the respondents serve. As shown in Table 52, 95% of overall weighted sales in the last 12 months were LED.

Table 52: Manufacturer Rep Sales by Technology

	Technology						
	LED	MH	HPS	LPS	Lin. FL	CFL	Other
Minimum	68%	0%	0%	0%	0%	0%	0%
Maximum	100%	5%	29%	10%	0%	0%	0%
Average	95%	1%	3%	1%	0%	0%	0%
Weighted	95%	2%	2%	1%	0%	0%	0%

Of the 11 respondents, 4 exclusively sell LED. TRC asked why they choose to only sell LED and their responses were the following:

- ◆ “LEDs are the future.”
- ◆ “[LEDs have] lower maintenance requirements.”
- ◆ “Clients only request LEDs.”
- ◆ “LEDs interact with controls better.”
- ◆ “Title 24 requirements are difficult to meet with other technologies.”

The respondents who sell 95% or less LEDs described their non-LED sales as the following:

- ◆ “Some clients ask for HID for decorative considerations.”
- ◆ “Dark Sky requirements use LPS.”
- ◆ “During renovations, clients want to keep the same look as before.”
- ◆ “Clients request consistency between the existing building and new building.”

TRC asked if LED sales are dependent on customer type among the following: large retail, small retail, large grocery, small grocery, large offices, small offices, restaurants, K-12 school, college or university, multifamily,

hospital and large healthcare building, roadways and streetscapes, and other. Three respondents sell only to distributors and electrical contractors and were unable to answer this question. The remaining responses indicated no clear distinctions in LED sales by business type; all reported that the vast majority of their sales are LEDs, regardless of customer type. However, three respondents reported lower LED usage for restaurants and multifamily.

Next, TRC asked about LED sales by product category. Table 53 shows results.

Table 53: Manufacturer Rep Sales by Technology, by Product Category

Product Categories									
	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Pool	Street Sign
Minimum	70%	40%	70%	70%	1%	90%	30%	95%	95%
Maximum	100%	100%	100%	100%	100%	100%	100%	100%	100%
Average	96%	92%	94%	96%	84%	98%	91%	99%	97%
Weighted Average	96%	93%	95%	97%	87%	98%	93%	98%	95%

7.3.2 DLC Designation and Efficacy for LED sales

TRC asked the respondents about the DLC designation of the LED products they sell for new construction and for retrofits. One respondent did not know the DLC designation of their products. Three respondents were not able to distinguish DLC Premium versus standard, but they could estimate the fraction of their sales that were DLC listed. Table 54 shows the results. The values with the highest accuracy are those showing DLC listed (84% for New Construction and 86% for Retrofits) and non-DLC listed (16% for New Construction and 14% for Retrofits), since they reflect ten responses.

Table 54: Manufacturer Rep Responses to DLC Listing for New Construction and Retrofit Projects

	New Construction				Retrofit			
	DLC Premium	DLC Standard	DLC Listed	Non-DLC	DLC Premium	DLC Standard	DLC Listed	Non-DLC
Minimum	0%	0%	50%	0%	10%	0%	63%	0%
Maximum	100%	100%	100%	50%	100%	75%	100%	38%
Average	39%	46%	82%	18%	50%	37%	89%	11%
Weighted Average	40%	42%	84%	16%	54%	28%	86%	14%

These values show that DLC listed products dominate sales. Of the seven respondents that could distinguish DLC Premium from DLC Standard sales, six reported that their DLC Premium sales were higher for retrofits compared to new construction. Many respondents reported that customers do not care about DLC designation unless the project qualifies for a rebate. One respondent who primarily serves municipal customers reported that every city has different preferences regarding DLC.

TRC asked the respondents to estimate their breakdown of LED sales by either DLC-designation, or by efficacy, for each product category. Three respondents were able to classify their products in efficacy bins. Five respondents opted to classify their products by DLC designation. Two respondents only classified their product as DLC listed or not. TRC converted the responses that provided efficacy estimates for each category to DLC

designation, based on the DLC efficacy requirements for typical lumen outputs for that product category. The results are provided in Table 55 below.

Table 55: Manufacturer Rep DLC designation by Product Category

Product Category	DLC designation				
		DLC Premium	DLC Standard	Listed	Non-DLC Listed
Streetlight	Minimum	0%	0%	0%	0%
	Maximum	100%	50%	100%	100%
	Average	41%	18%	64%	36%
	Weighted Average	35%	20%	73%	28%
Pole Mount	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	48%	26%	69%	31%
	Weighted Average	37%	25%	80%	20%
Wall Mount	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	42%	33%	78%	22%
	Weighted Average	36%	30%	85%	15%
Floodlight	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	36%	43%	73%	27%
	Weighted Average	29%	35%	83%	17%
Bollard	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	31%	34%	62%	38%
	Weighted Average	23%	25%	65%	35%
Fuel Canopy	Minimum	0%	0%	50%	0%
	Maximum	100%	100%	100%	50%
	Average	53%	35%	88%	13%
	Weighted Average	53%	31%	85%	15%
Parking Garage	Minimum	0%	0%	30%	0%
	Maximum	100%	100%	100%	70%
	Average	47%	45%	85%	15%
	Weighted Average	40%	41%	86%	14%
Pool	Minimum	0%	0%	0%	15%
	Maximum	30%	55%	85%	100%
	Average	10%	18%	28%	72%
	Weighted Average	8%	14%	21%	79%
Street Sign	Minimum	50%	0%	50%	10%
	Maximum	55%	35%	90%	50%
	Average	53%	18%	70%	30%
	Weighted Average	57%	25%	70%	30%

Respondents reported the following challenges in selling DLC Premium products:

- ◆ “Customers do not ask about DLC unless it is necessary [for rebates and programs].”
- ◆ “Price is the driving factor for sale, not DLC or efficacy,”
- ◆ “[There are a] lack of options for Dark Sky LED products.”

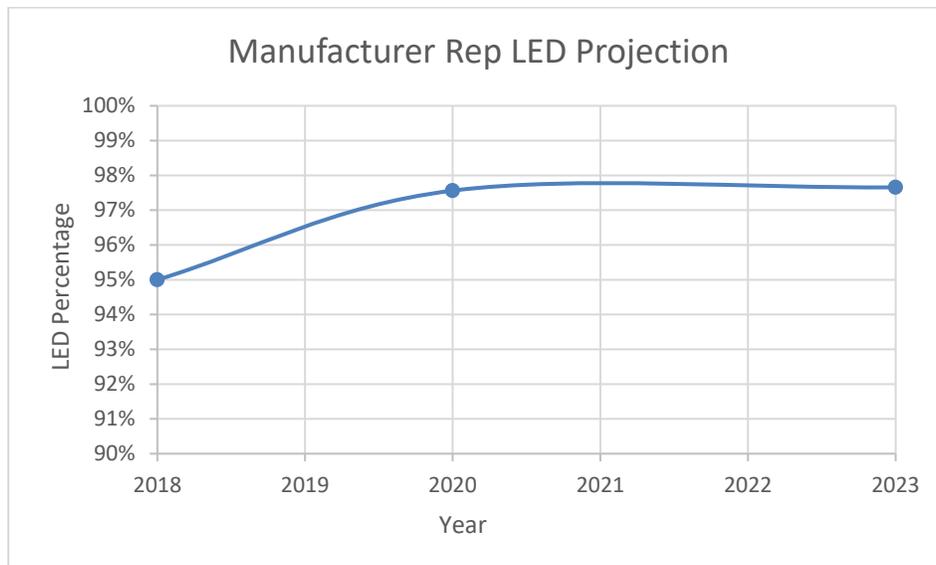
7.3.3 Projections of LED Penetration

Four respondents currently sell 100% LEDs. Most other respondents projected their penetration of LEDs to increase to 100% or close to 100%, and do not anticipate any laggards to LED adoption by product category. Several commented that they expect LEDs to increase to 100% (or close to 100%) “unless a better technology comes along”. One respondent projected that the penetration of LEDs will increase in two years to 99%; however, in five years, it will have significantly decreased to 93%. The respondent cited research on new incandescent technology with heat recovery that the respondent thinks will be more efficient and cost less than LEDs. All others estimated an increase in LED sales in two years. Five expected the market to be 100% LEDs in two years and continue to be 100% to five years. Two respondents estimated that it will top out in two years, one estimated 99% and another at 95%. Three respondents estimated a steady increase in two and five years. Table 56 shows the results. Note that there is no difference in projected penetration between new construction and retrofit projects.

Table 56: Manufacturer Rep Projections of LED Penetration

	New Construction		Retrofits and Renovation	
	2 Years	5 Years	2 Years	5 Years
Minimum	80%	90%	85%	93%
Maximum	100%	100%	100%	100%
Average	97%	98%	98%	99%
Weighted Average	98%	98%	98%	98%

Figure 21: Manufacturer Rep Projections of LED Penetration



TRC asked if their projections differed by product category, but respondents did not indicate any difference in LED adoption by product category.

7.3.4 Replaced Technologies

TRC asked survey respondents what existing technologies are replaced in their retrofits projects. Table 57 shows results.

Table 57: Manufacturer Rep Responses to Technologies Retrofitted, by Product Category

Product Category		Technology Retrofitted						
		LED	MH	HPS	LPS	Lin. FL	CFL	Other
Street Lighting (n=10)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	10%	100%	95%	100%	20%	0%	8%
	Average	1%	31%	36%	19%	4%	0%	1%
	Weighted Average	1%	39%	40%	16%	3%	0%	1%
Pole Mount (n=8)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	20%	90%	95%	60%	10%	0%	8%
	Average	3%	39%	36%	23%	1%	0%	1%
	Weighted Average	2%	35%	31%	14%	1%	0%	1%
Wall Mount (n=8)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	80%	75%	50%	0%	50%	13%
	Average	0%	48%	24%	7%	0%	19%	2%
	Weighted Average	0%	48%	26%	3%	0%	20%	3%
Floodlight (n=8)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	100%	75%	50%	30%	20%	40%
	Average	0%	58%	19%	6%	4%	4%	8%
	Weighted Average	0%	49%	22%	2%	4%	4%	9%
Bollard (n=8)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	60%	99%	50%	0%	50%	0%
	Average	0%	40%	31%	6%	0%	20%	0%
	Weighted Average	0%	46%	28%	2%	0%	21%	0%
Fuel Canopy (n=4)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	100%	50%	30%	100%	0%	0%
	Average	0%	55%	13%	8%	25%	0%	0%
	Weighted Average	0%	55%	13%	8%	25%	0%	0%
Parking Garage (n=8)	Minimum	0%	0%	0%	0%	0%	0%	0%
	Maximum	0%	98%	30%	100%	100%	0%	1%
	Average	0%	46%	8%	13%	29%	0%	0%
	Weighted Average	0%	40%	9%	5%	31%	0%	0%
Street Sign (n=2)	Minimum	0%	50%	0%	0%	0%	0%	0%
	Maximum	60%	60%	50%	50%	50%	0%	0%
	Average	0%	55%	20%	0%	25%	0%	0%
	Weighted Average	0%	55%	20%	0%	25%	0%	0%

Respondents reported that metal halide is the most common technology that is replaced, followed by HPS. LPS and linear fluorescents are commonly retrofitted in some categories. Technologies in the *other* category are halogen, incandescent and mercury vapor.

For street sign lighting and pool lighting, TRC did not survey enough manufacture reps that sell these products to quantitatively analyze results. One manufacturer rep sells pool lighting and reported that pool light retrofits are approximately 50% metal halide and 50% incandescent/ halogen. Two manufacturer reps sell street sign lighting. Both reported that approximately half of these retrofits replace metal halides; one rep reported the remainder replace HPS, while the other rep reported the remainder replace linear fluorescents.

7.3.5 Barriers to Exterior Lighting Retrofits

TRC asked about barriers to implementing a retrofit, and why some customers choose to continue to only replace failed lamps and fixtures. Nine respondents provided a response, and all nine respondents indicated cost as a barrier. Because TRC framed the question as open-ended, respondents used different word choices, including price, cost, budget, or financial considerations. Other comments included:

- ◆ “Clients do not understand the true cost of postponing a retrofit which include operation and maintenance costs”
- ◆ “Unlike tenants, reducing consumption does not benefit owners so they are uninterested in the investment.”
- ◆ “Municipal clients typically already have an inventory of old, replacement parts/”
- ◆ “Clients are interested in maintaining a certain look or feel.”

7.4 Maintenance Contractor Survey Responses

This section provides responses from maintenance contractor surveys. Six of the eleven respondents were referrals from IOU staff members, and TRC identified the other five through online research. TRC notes where responses appeared to vary according to whether the respondent was an IOU referral.

TRC asked respondents which of the nine product categories their office maintains for their client base. Respondents answered with a yes, no, or occasionally for each product category.

Pole-mounted, wall mounted, bollard, and flood and spot lighting were the most common types of product categories maintained. Most respondents indicated that that they maintain streetlighting for their clients. Few respondents maintain fuel canopies, pool lighting, or street sign lighting. Table 58 shows the results.

Table 58: Number of Maintenance Contractors Surveyed that Maintain each Product Category

Response	Product Categories								
	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Pool	Street Sign
Yes	5	10	9	9	6	3	9	2	3
No	4	0	1	1	0	7	2	9	8
Occasionally	2	1	1	1	5	1	0	0	0

7.4.1 Installations by Construction Type

Although the focus of the survey was installations for new construction and retrofits, TRC asked respondents to provide an approximate breakdown of the percentage of exterior fixture installations in California in the past 12 months that go to new construction, retrofits, and replacements. TRC defined new construction as any new

building or addition to existing building, retrofits as replacements or updates to all exterior fixtures in an area, and replacements as replacements of individual failed products. Table 59 shows results.

Table 59: Percent of Contractor Fixture Installations that are New Construction, Retrofits, and Replacements

Product Category		Construction Type		
		New Construction	Retrofits	Replacements (Maintenance)
Streetlight	Minimum	0%	15%	0%
	Maximum	50%	100%	80%
	Average	11%	69%	19%
	Weighted Average	10%	80%	9%
Pole Mount	Minimum	0%	0%	0%
	Maximum	80%	98%	100%
	Average	17%	56%	28%
	Weighted Average	12%	69%	19%
Wall Mount	Minimum	0%	0%	0%
	Maximum	80%	98%	100%
	Average	13%	46%	31%
	Weighted Average	6%	56%	25%
Floodlight	Minimum	0%	0%	0%
	Maximum	80%	98%	100%
	Average	12%	47%	31%
	Weighted Average	5%	56%	25%
Bollard	Minimum	0%	0%	0%
	Maximum	90%	98%	100%
	Average	13%	46%	41%
	Weighted Average	6%	56%	38%
Fuel Canopy	Minimum	0%	0%	0%
	Maximum	5%	95%	90%
	Average	1%	46%	28%
	Weighted Average	1%	53%	37%
Parking Garage	Minimum	0%	0%	0%
	Maximum	50%	98%	80%
	Average	9%	61%	19%
	Weighted Average	9%	72%	15%
Pool	Minimum	0%	30%	0%
	Maximum	30%	100%	40%
	Average	15%	65%	20%
	Weighted Average	8%	83%	10%
Street Sign	Minimum	0%	30%	0%
	Maximum	50%	100%	30%
	Average	30%	60%	10%
	Weighted Average	27%	69%	4%

As shown in Table 59, respondents indicated that retrofits accounted for the clear majority of exterior fixture installations for all types of product categories. Replacement were the second most common installation type, followed by new construction, except for street-lighting and street sign lighting.

The maintenance contractor responses varied much more by respondent than product category. In other words, most contractors reported either a very low percentage of their fixtures were replacements for all product categories, or that a very high percentage were replacements for all product categories. Table 60 presents this finding by grouping contractors according to their response for all product categories. As shown, seven contractors reported that their replacements comprised 0-20% of their exterior fixture installations, while three contractors reported that replacements dominated their exterior fixture installations (70-100%). The only respondent that fell in the middle of these extremes reported 30-40% of their installations were replacements for all product categories. Table 60 shows the results.

Table 60: Maintenance Contractor Responses to Percent of Installations that are Replacements

Exterior Fixture Installations that are Replacements (%) ³⁵	Number of Respondents	TRC’s Assessment of Primary Activity
0-20%	7	Primarily retrofits
30-40%	1	Mix of retrofits and maintenance
70-100%	3 ³⁶	Primarily maintenance

The difference in results suggest that some contractors’ business models is to target retrofits, while others primarily maintain systems for customers. The results shown here may be skewed towards a higher percentage of retrofits and lower percentage of maintenance installations, because six of the eleven maintenance contractors surveyed were IOU referrals, which are likely to have a significant retrofit practice. In addition, because the survey focused on fixtures, TRC asked respondents to estimate their exterior *fixture* installations for new construction, retrofit, versus replacement, not their total exterior installations, which would include *lamps and fixtures*. The fraction of installations that are lamps and fixtures is likely higher than the results shown in Table 59 and Table 60.

7.4.2 Installations by Technology

TRC asked respondents to provide the overall breakdown of total exterior lighting installations for new construction and retrofits, by percent, based on seven light source technologies: LED, MH, HPS, LPS, linear fluorescent, CFL, and other.

Six respondents, five of which were IOU referrals, indicated that 100 percent of exterior lighting installations are LED. The sixth referral respondent indicated that 98 percent of exterior lighting installations are LED. For the five contractors that TRC found via web research, one reported that LEDs comprise 43% of installations, two reported LEDs comprise 60% of fixture installations, one reported 90%, and the final reported 100%. Thus, LEDs comprise the majority of fixture installations for new construction and retrofits, even among non-IOU referrals.

³⁵ Based on responses to all product categories except pool lighting and street sign lighting. Two respondents serviced pool lighting, and one reported he only provided retrofits (no replacements) for that category and the other reporting that 40% of his installations are replacements. For the three contractors that service street sign lighting, two reported they never do replacements for this category, and the third reported that 30% of his installation are replacements.

³⁶ One respondent in this group estimated 70-100% replacements for all product categories except parking garages.

Overall, most of exterior installations are LED, with four respondents noting that metal halide comprises a significant share of fixtures, and two respondents reporting that HPS still comprise some installations. Table 61 shows the results.

Table 61: Maintenance Contractors Installations by Technology

	Technology						
	LED	MH	HPS	LPS	Linear FL	CFL	Other
Minimum	43%	0%	0%	0%	0%	0%	0%
Maximum	100%	40%	21%	5%	5%	0%	0%
Average	86%	9%	4%	0%	0%	0%	0%
Weighted Average	89%	9%	1%	0%	0%	0%	0%

TRC asked respondents to estimate if the LED percentage is higher, lower, or the same for each product category for new construction and retrofits. Respondents reported that the percentage of LED was approximately the same across all product categories except for parking garages and streetlighting. One respondent stated that the percentage of LED for parking garages was higher while another respondent stated that the percentage of LED was lower. For streetlighting, two respondents stated the percentage of LED was higher while two other respondents stated the percentage of LED was lower.

TRC asked respondents what customer types they typically serve, and whether the penetration of LEDs in exterior fixture installations vary by customer type. All respondents served at least three customer types and there were at least two respondents that served each customer type identified by TRC (based on DEER categories: large retail, small retail, large grocery, small grocery, large office, small office, restaurant, K-12 school, college or university, multifamily, hospital, municipal project, other). In general, respondents reported there were no major laggards to LED adoption for new construction and retrofits, and that the percent of installations that are LEDs does not vary significantly by customer type. One participant noted that smaller customers had a lower LED installation rate than large customers of the same customer type.

7.4.3 DLC Designation for LED Installations

TRC asked respondents for the percentage of exterior LED fixtures installed on the DLC Qualified Products Listing. Several respondents were not able to distinguish between DLC Premium and DLC Standard. Of the eleven respondents, nine indicated they installed DLC products, one installed previously purchased stock and did not know if any products were DLC listed, and one respondent indicated they worked strictly on new construction and thus this question was not applicable. Seven of the nine respondents who installed DLC listed products were able to distinguish between DLC Premium and DLC Standard. Table 62 presents the results. In general, contractors that were IOU referrals reported a higher fraction of DLC Premium products than contractors that TRC identified via web research. A few respondents reported that they install mostly DLC Premium products to capture rebates.

Table 62: Maintenance Contractor Installations by DLC Designation

	Fraction of Installations by DLC Designation		
	DLC Premium	DLC Standard	Non-DLC
Minimum	10%	0%	0%
Maximum	100%	60%	30%
Average	66%	27%	7%
Weighted Average	75%	22%	3%

TRC asked respondents if the DLC Premium and standard listing percentages differ (higher or lower) for each product category. Respondents indicated that the percentage of DLC Premium and standard listings were approximately the same across product categories.

7.4.4 Projections of LED Penetration

TRC asked respondents for their projections of the fraction of exterior fixture installations that will be LEDs in two and five years for retrofits and new construction. All respondents indicated that the percentage of LEDs would increase. Seven respondents projected 100 percent LEDs in two years, two respondents projected LEDs would be greater than 90 percent but less than 100 percent in two years, and two respondents indicated that LEDs would be around 60 percent in two years.

TRC asked respondents to approximate the percentage of LED exterior fixture installations they expect in five years. Nine respondents expected 100 percent of exterior fixture installations to be LED, one respondent expected 75 percent of exterior fixture installations to be LED, and one respondent expected 70 percent of exterior fixture installations to be LED. Table 63 shows the results.

Table 63: Maintenance Contractor Projections of Penetrations of LEDs

New Construction and Retrofit		
	2 Years	5 Years
Minimum	60%	70%
Maximum	100%	100%
Average	92%	95%
Weighted Average	96%	98%

TRC asked respondents if there is any product category that lag behind these projections. In general, respondents did not identify product categories that would be laggards. For new construction and retrofits, eight respondents indicated that all product categories would be 100 percent LED, two respondents indicated that there would be product categories not at 100 percent LED, and one respondent had to skip this question due to time restraints. Of the two respondents that stated not 100 percent LED, one respondent stated adoption of LEDs would be around 70 percent for all product categories and the other said parking garages will have about 60 percent LEDs with the remaining 40 percent being linear fluorescent.

7.4.5 Replaced Technologies

TRC asked respondents the light source technology replaced in exterior lighting system retrofits, for each product category. If survey time allowed, the surveyor asked the respondent for quantitative responses – i.e., to estimate the fraction of technologies retrofitted for each product category. If there was less survey time available, the surveyor asked the respondent to identify the main technologies retrofitted for each product category.

Respondents reported:

- ◆ Streetlighting retrofits mainly replace LPS with some MH.
- ◆ Pole-mounted retrofits mainly replace MH, some HPS, and one respondent stated fluorescent.
- ◆ Wall mount, floodlighting, and bollard retrofits main replace MH, some HPS, and a little fluorescent.
- ◆ Fuel canopy retrofits usually replace LPS.
- ◆ Parking garage retrofits usually replace linear fluorescent, with some MH and HPS.

7.4.6 Barriers to Retrofits and Lamp Replacements

TRC asked respondents why some customers continue to replace failed fixtures and lamps, one-off as they fail, instead of implementing a retrofit. Six respondents reported that price was a barrier, and one respondent stated there were no barriers.³⁷ A few respondents indicated that property managers typically want to replace on burn out and not implement full scale retrofits.

TRC asked respondents if exterior fixture and lamp replacements installed the same technology as what was removed or replaced the failed product with a different technology. Eight contractors provided responses, and all but one respondent indicated the majority of exterior fixture and lamp replacements were replaced with the same technology. One respondent stated that all replacements are LED unless there is no LED alternative available, mostly in the case of decorative fixtures.

7.5 Market Actor Estimates of Sales by DLC Designation for each Product Category

TRC asked market actors to estimate their sales by DLC designation for each product category. Table 64 shows results for manufacturers and manufacturer reps, and the weighted average values across these market actors. TRC did not include results from maintenance contractors in this figure, because several may have skewed result (towards DLC Premium) because of IOU rebates, and a few could not reliably discern between DLC Standard and DLC Premium.

Because results were similar for each product category, and some categories had responses from only a few market actors, TRC assumed the values for their responses to DLC designation for overall exterior fixtures, shown in Table 24 in Section 4.2.3, when calculating standard practice efficacy and pricing.

Table 64: Estimates of Sales by DLC Designation for Each Product Category

Product Category	Value	DLC Premium	DLC Standard	DLC Listed	Non-DLC Listed
Streetlight	Manufacturers				
	Minimum	0%	50%	90%	0%
	Maximum	40%	100%	100%	10%
	Average	18%	79%	97%	4%
	Weighted Average	18%	78%	97%	3%
	Manufacturer Reps				
	Minimum	0%	0%	0%	0%
	Maximum	100%	50%	100%	100%
	Average	41%	18%	64%	36%
	Weighted Average	35%	20%	73%	28%
	Weighted Average across Market Actors	24%	59%	89%	11%

³⁷ Four respondents did not provide a response, either because they do not do replacement projects due to their business model, or because the survey skipped this question due to lack of time.

Product Category	Value	DLC Premium	DLC Standard	DLC Listed	Non-DLC Listed
Pole Mount	Manufacturers				
	Minimum	5%	0%	85%	0%
	Maximum	100%	91%	100%	15%
	Average	38%	55%	93%	7%
	Weighted Average	28%	65%	93%	7%
	Manufacturer Reps				
	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	48%	26%	69%	31%
	Weighted Average	37%	25%	80%	20%
	Weighted Average across Market Actors	31%	52%	89%	11%
Wall Mount	Manufacturers				
	Minimum	0%	50%	70%	0%
	Maximum	20%	100%	100%	30%
	Average	11%	82%	93%	9%
	Weighted Average	11%	81%	92%	8%
	Manufacturer Reps				
	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	42%	33%	78%	22%
	Weighted Average	36%	30%	85%	15%
	Weighted Average across Market Actors	20%	64%	90%	10%
Floodlight	Manufacturers				
	Minimum	0%	13%	13%	0%
	Maximum	45%	91%	100%	88%
	Average	22%	51%	73%	27%
	Weighted	24%	57%	81%	19%
	Manufacturer Reps				
	Minimum	0%	13%	13%	0%
	Maximum	45%	91%	100%	88%
	Average	22%	51%	73%	27%
	Weighted	24%	57%	81%	19%
	Weighted Average across Market Actors	24%	57%	81%	19%

Product Category	Value	DLC Premium	DLC Standard	DLC Listed	Non-DLC Listed
Bollard	Manufacturers				
	Minimum	0%	20%	20%	0%
	Maximum	25%	100%	100%	80%
	Average	8%	59%	67%	33%
	Weighted	8%	58%	65%	35%
	Manufacturer Reps				
	Minimum	0%	0%	0%	0%
	Maximum	100%	100%	100%	100%
	Average	31%	34%	62%	38%
	Weighted	23%	25%	65%	35%
	Weighted Average across Market Actors	13%	47%	65%	35%
Fuel Canopy	Manufacturers				
	Minimum	0%	1%	80%	0%
	Maximum	99%	91%	100%	20%
	Average	54%	42%	95%	5%
	Weighted	48%	47%	95%	5%
	Manufacturer Reps				
	Minimum	0%	0%	50%	0%
	Maximum	100%	100%	100%	50%
	Average	53%	35%	88%	13%
	Weighted	53%	31%	85%	15%
	Weighted Average across Market Actors	49%	42%	91%	8%
Parking Garage	Manufacturers				
	Minimum	2%	8%	10%	0%
	Maximum	50%	91%	100%	90%
	Average	15%	52%	68%	32%
	Weighted	15%	50%	65%	35%
	Manufacturer Reps				
	Minimum	0%	0%	30%	0%
	Maximum	100%	100%	100%	70%
	Average	47%	45%	85%	15%
	Weighted	40%	41%	86%	14%
	Weighted Average across Market Actors	23%	47%	72%	28%

7.6 Product Pricing and Efficacy Results

7.6.1 Product Efficacy Results

The following tables present the efficacy of the approximately 800 lighting products collected from manufacturer representatives pricing requests and online sources.

Table 65: Efficacy Results by DLC Designation: Streetlight and Pole Mount

Lumens		Streetlight			Pole Mount		
		Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium
Low Output <5k	Min	75	97	117	61	105	113
	Max	107	109	135	116	105	139
	Median	81	105	126	97	105	121
	Mean	84	104	125	91	105	123
	Qty	7	6	11	13	1	10
Mid Output 5k-10k	Min	67	99	115	54	96	115
	Max	115	114	128	118	114	128
	Median	81	102	122	93	110	121
	Mean	81	104	122	89	107	122
	Qty	20	22	12	19	9	12
High Output 10k-30k	Min	77	101	121	77	102	120
	Max	123	118	136	125	119	146
	Median	91	107	127	95	112	127
	Mean	90	108	128	95	112	128
	Qty	28	35	22	11	39	50
Very High Output 30k and up	Min	N/A	N/A	131	107	101	120
	Max	N/A	N/A	135	117	120	148
	Median	N/A	N/A	133	116	110	128
	Mean	N/A	N/A	133	114	109	129
	Qty	0	0	2	4	21	12

Table 66: Efficacy Results by DLC Designation: Wall Mount and Floodlight

Lumens	Wall Mount			Floodlight			
	Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium	
Low Output <5k	Min	26	92	112	48	90	114
	Max	120	109	125	111	109	146
	Median	82	101	118	80	100	122
	Mean	76	100	118	79	100	125
	Qty	63	13	12	25	13	4
Mid Output 5k-10k	Min	71	96	116	70	99	118
	Max	126	115	128	124	114	143
	Median	100	110	125	97	112	122
	Mean	98	106	123	101	109	126
	Qty	18	11	5	16	8	4
High Output 10k-30k	Min	95	110	125	90	105	121
	Max	113	119	125	102	118	137
	Median	105	117	125	93	111	127
	Mean	105	115	125	94	111	127
	Qty	5	7	1	13	17	5
Very High Output 30k and up	Min	N/A	N/A	N/A	90	105	120
	Max	N/A	N/A	N/A	92	113	120
	Median	N/A	N/A	N/A	91	110	120
	Mean	N/A	N/A	N/A	91	109	120
	Qty	0	0	0	5	6	1

Table 67: Efficacy Results by DLC Designation: Bollard and Fuel Canopy

Lumens	Bollard			Fuel Canopy			
	Non-DLC	DLC Standard	DLC Premium	Non-DLC	DLC Standard	DLC Premium	
Low Output <5k	Min	18	N/A	N/A	74	N/A	113
	Max	87	N/A	N/A	126	N/A	138
	Median	52	N/A	N/A	81	N/A	126
	Mean	54	N/A	N/A	86	N/A	127
	Qty	32	0	0	8	0	10
Mid Output 5k-10k	Min	N/A	N/A	N/A	95	103	120
	Max	N/A	N/A	N/A	120	114	151
	Median	N/A	N/A	N/A	101	113	124
	Mean	N/A	N/A	N/A	106	111	127
	Qty	0	0	0	5	4	13
High Output 10k-30k	Min	N/A	N/A	N/A	98	108	122
	Max	N/A	N/A	N/A	116	116	139
	Median	N/A	N/A	N/A	110	115	126
	Mean	N/A	N/A	N/A	108	113	128
	Qty	0	0	0	3	4	8

TRC did not identify bollard or fuel canopy products greater than 30,000 lumens.

Table 68: Efficacy Results by DLC Designation: Parking Garage

		Parking Garage		
Lumens		Non-DLC	DLC Standard	DLC Premium
Low Output <5k	Min	82	90	113
	Max	135	109	136
	Median	105	105	123
	Mean	104	101	124
	Qty	6	6	9
Mid Output 5k-10k	Min	79	98	115
	Max	138	114	137
	Median	93	105	124
	Mean	102	106	125
	Qty	7	23	14
High Output 10k-30k	Min	99	104	120
	Max	134	119	126
	Median	125	112	121
	Mean	119	112	122
	Qty	3	6	8
Very High Output 30k and up	Min	N/A	N/A	N/A
	Max	N/A	N/A	N/A
	Median	N/A	N/A	N/A
	Mean	N/A	N/A	N/A
	Qty	0	0	0

7.6.2 Product Pricing Results

The following tables provide pricing projections for the exterior lighting products based on product category and DLC output grouping.

Table 69: Price Projections for 2019

2019 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$292	\$764	\$383	\$297	\$746	\$337	\$377
Mid Output 5k-10k	\$391	\$608	\$449	\$620	N/A	\$400	\$380
High Output 10k-30k	\$812	\$912	\$769	\$760	N/A	\$509	\$359
Very High Output 30k and up	\$1,416	\$1,039	N/A	\$2,082	N/A	N/A	N/A

Table 70: Price Projections for 2020

2020 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$266	\$697	\$349	\$271	\$681	\$307	\$344
Mid Output 5k-10k	\$356	\$554	\$409	\$565	N/A	\$365	\$346
High Output 10k-30k	\$741	\$832	\$702	\$693	N/A	\$464	\$328
Very High Output 30k and up	\$1,291	\$948	N/A	\$1,899	N/A	N/A	N/A

Table 71: Price Projections for 2021

2021 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$243	\$636	\$318	\$247	\$621	\$280	\$313
Mid Output 5k-10k	\$325	\$506	\$373	\$516	N/A	\$333	\$316
High Output 10k-30k	\$676	\$759	\$640	\$632	N/A	\$423	\$299
Very High Output 30k and up	\$1,177	\$864	N/A	\$1,732	N/A	N/A	N/A

Table 72: Price Projections for 2022

2022 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$221	\$580	\$290	\$226	\$566	\$255	\$286
Mid Output 5k-10k	\$296	\$461	\$340	\$470	N/A	\$304	\$288
High Output 10k-30k	\$616	\$692	\$584	\$577	N/A	\$386	\$273
Very High Output 30k and up	\$1,074	\$788	N/A	\$1,579	N/A	N/A	N/A

Table 73: Price Projections for 2023

2023 Price Projections	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage
Low Output <5k	\$202	\$529	\$265	\$206	\$516	\$233	\$261
Mid Output 5k-10k	\$270	\$421	\$310	\$429	N/A	\$277	\$263
High Output 10k-30k	\$562	\$631	\$532	\$526	N/A	\$352	\$249
Very High Output 30k and up	\$979	\$719	N/A	\$1,440	N/A	N/A	N/A

7.6.3 Analysis of Price versus Lumen Output

The following figures show trends in price versus output for each product category. These figures color-code data according to DLC-designation (premium, standard, or not listed). Some product categories indicate correlations below price and output, while others do not.

Figure 22: Price versus Output: Streetlight Fixtures

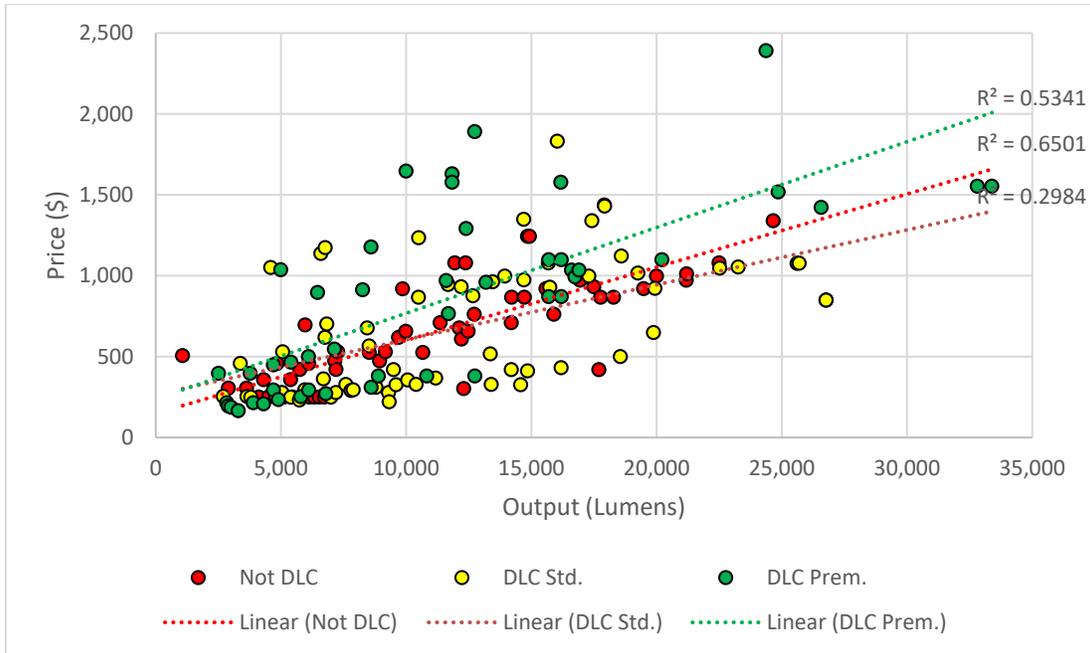


Figure 23: Price versus Output: Pole Mount

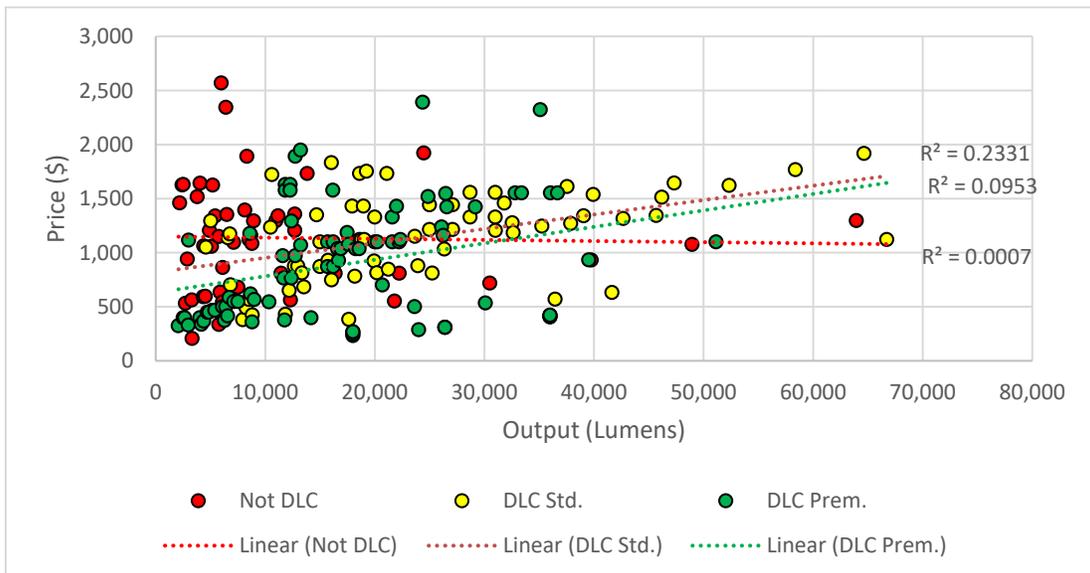


Figure 24: Price versus Output: Wall Mount

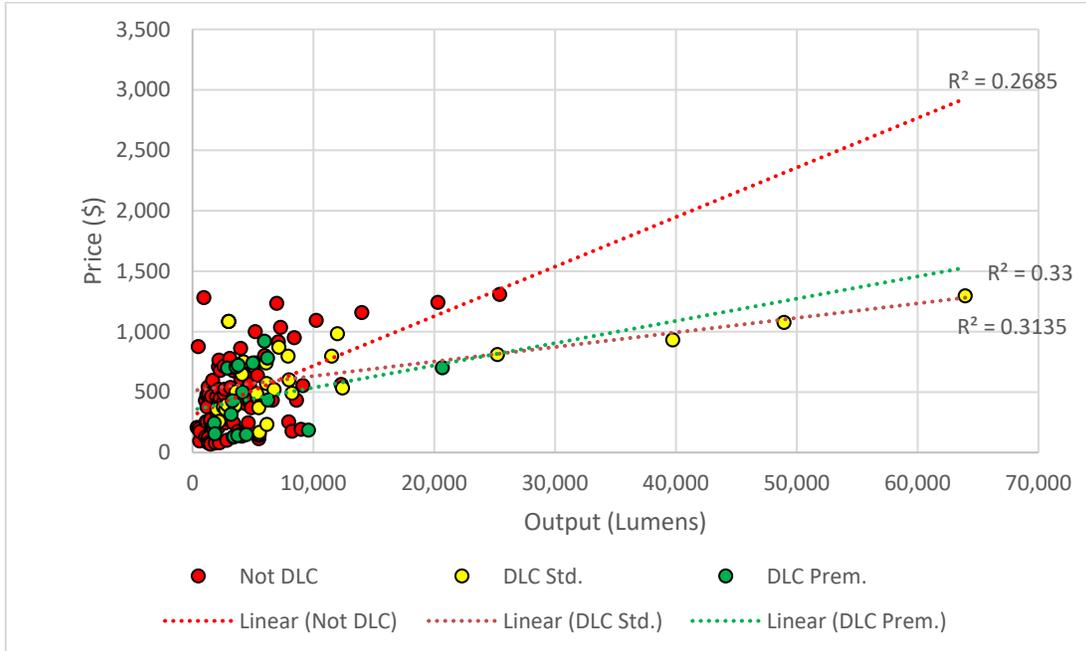


Figure 25: Price versus Output: Floodlight

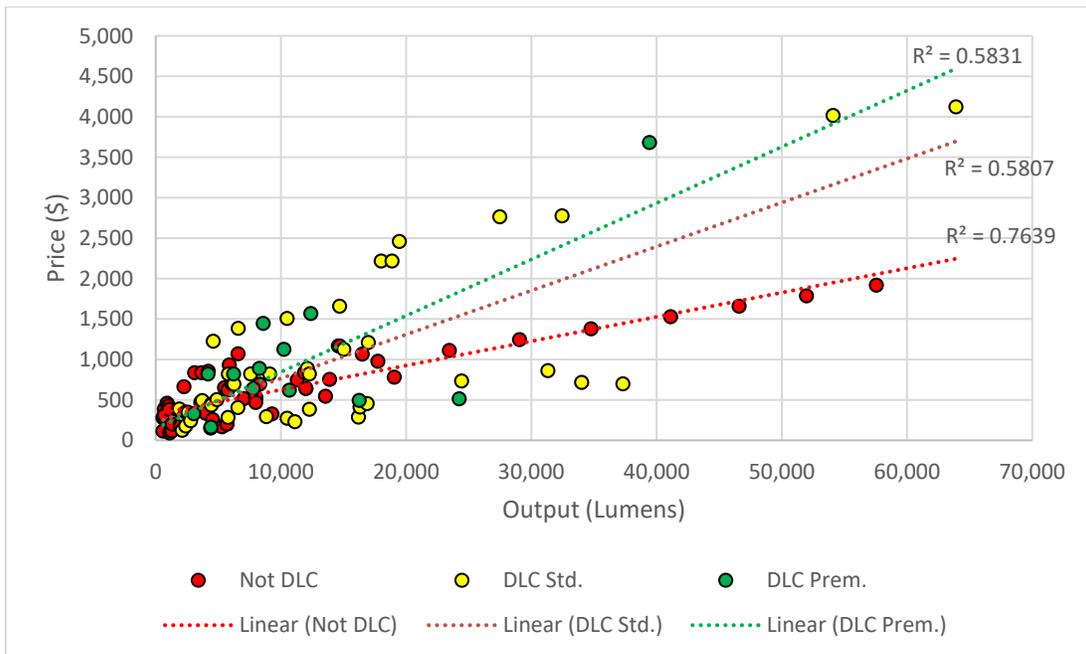


Figure 26: Price versus Output: Bollard

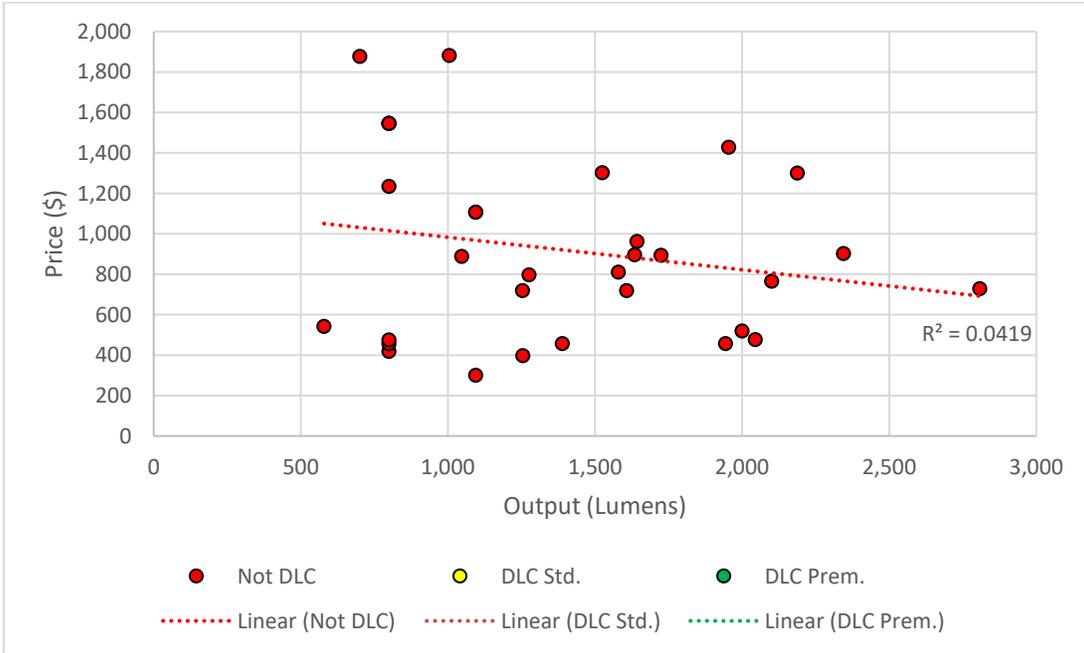


Figure 27: Price versus Output: Fuel Canopy

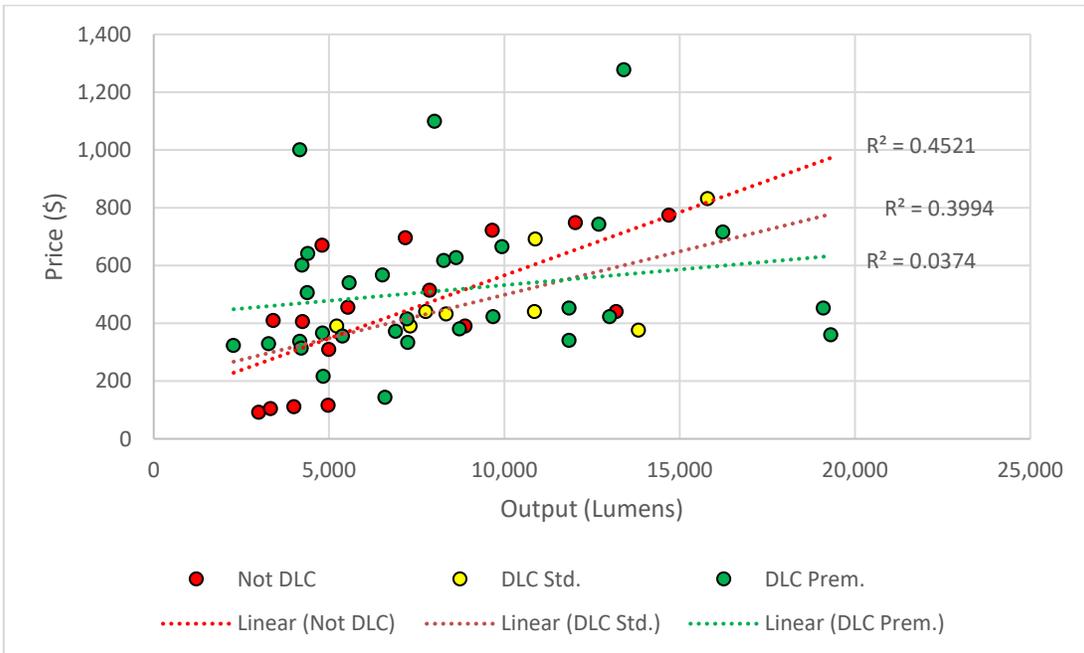
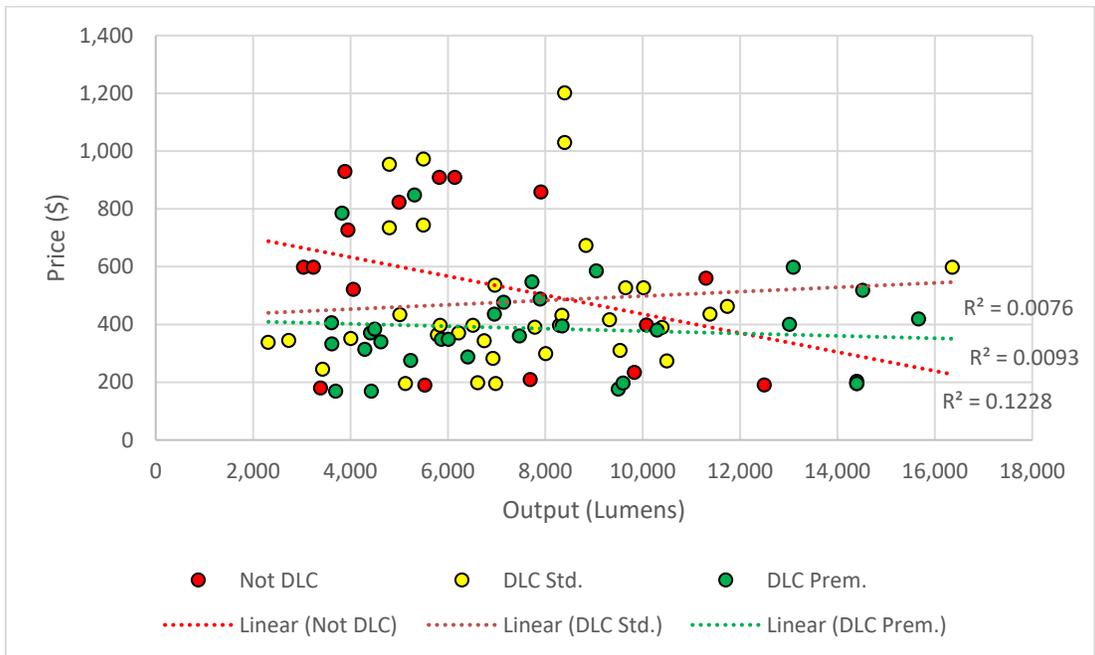


Figure 28: Price versus Output: Parking Garage



7.6.4 Analysis of Efficacy versus Wattage

The following figures show trends in efficacy compared with Wattage. This analysis did not identify trends in efficacy as product wattage changes. However, these figures help illustrate the range of efficacy found for different product types.

Figure 29: Efficacy versus Wattage: Streetlight

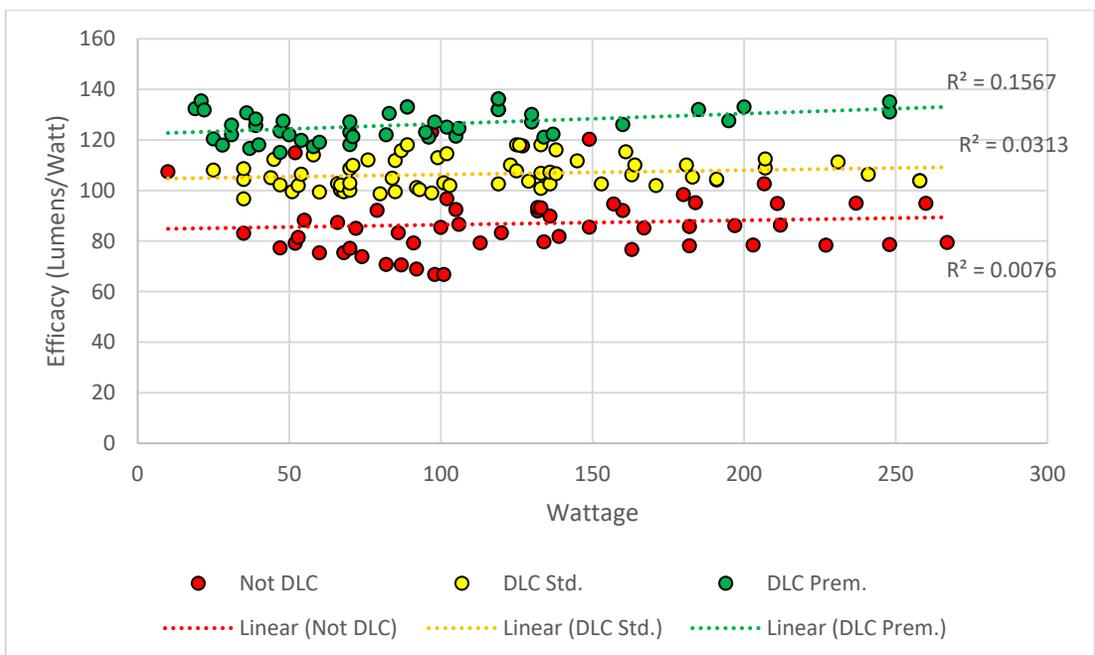


Figure 30: Efficacy versus Wattage: Pole Mount

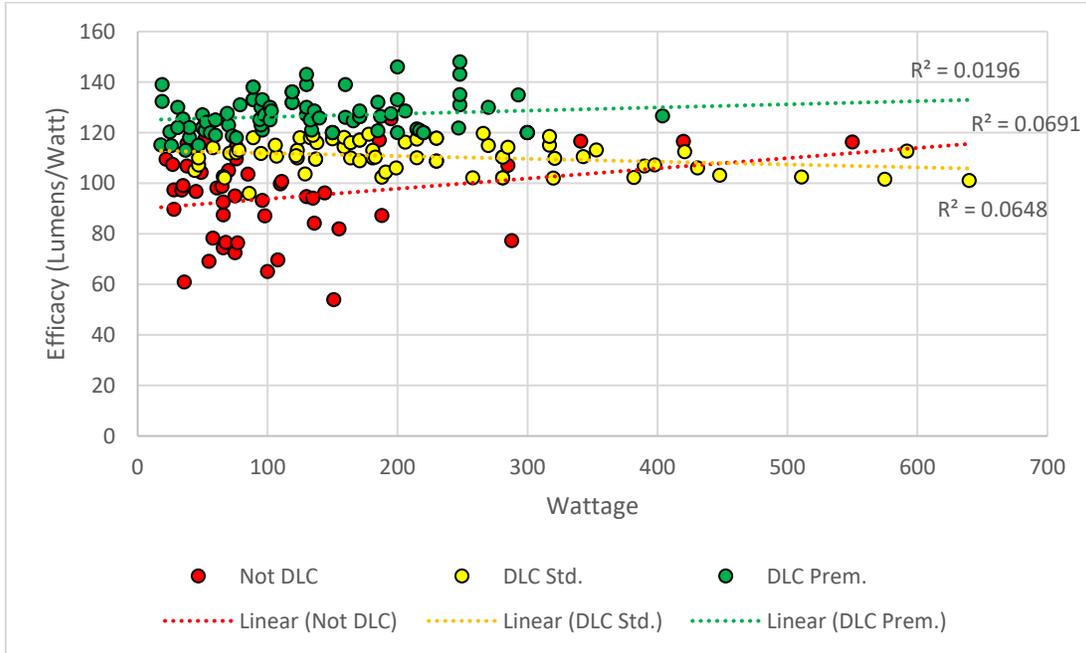


Figure 31: Efficacy versus Wattage: Wall Mount

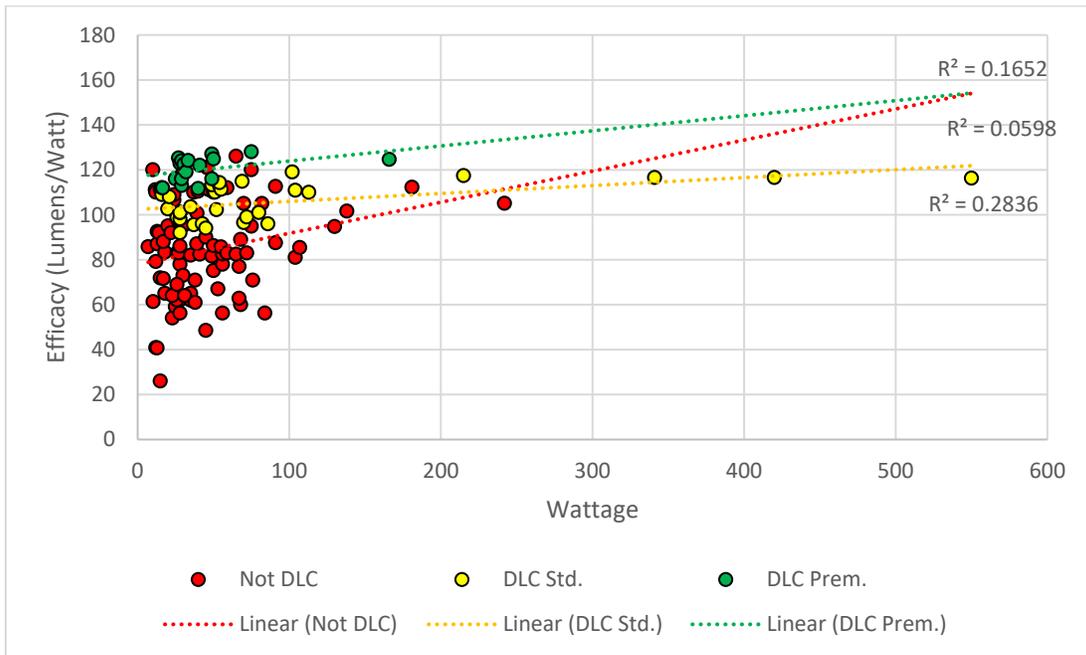


Figure 32: Efficacy versus Wattage: Floodlight

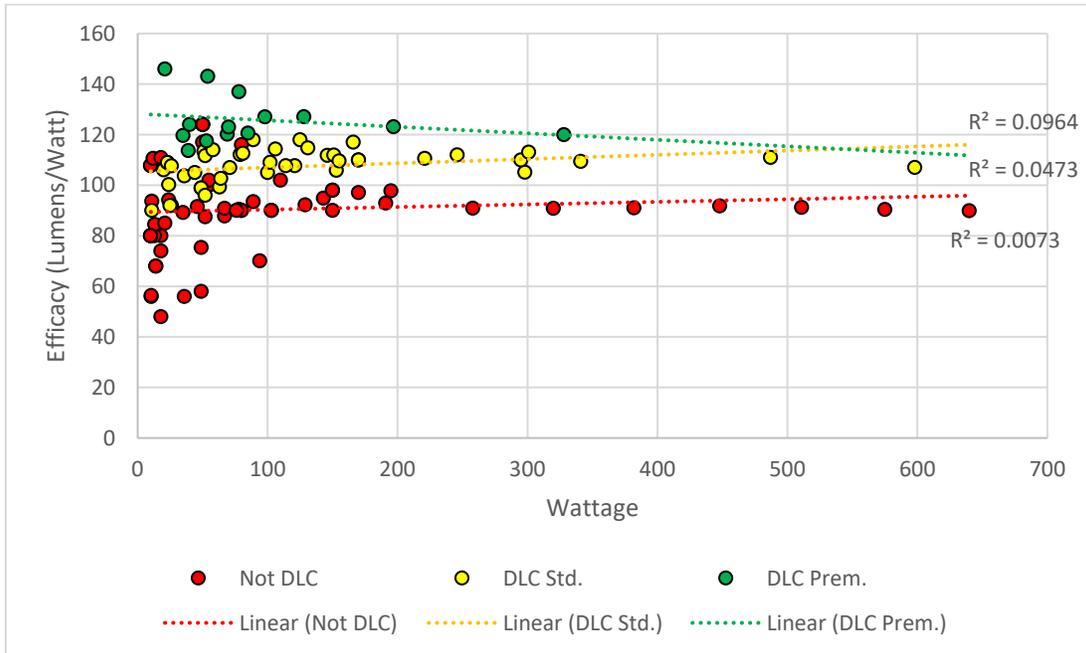


Figure 33: Efficacy versus Wattage: Bollard

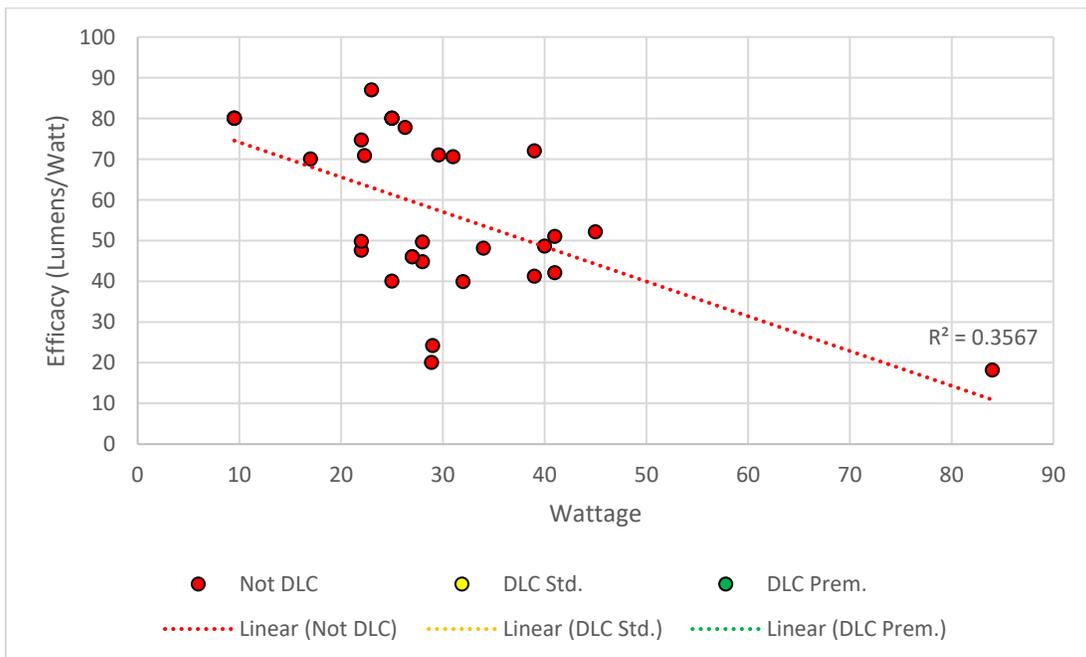


Figure 34: Efficacy versus Wattage: Fuel Canopy

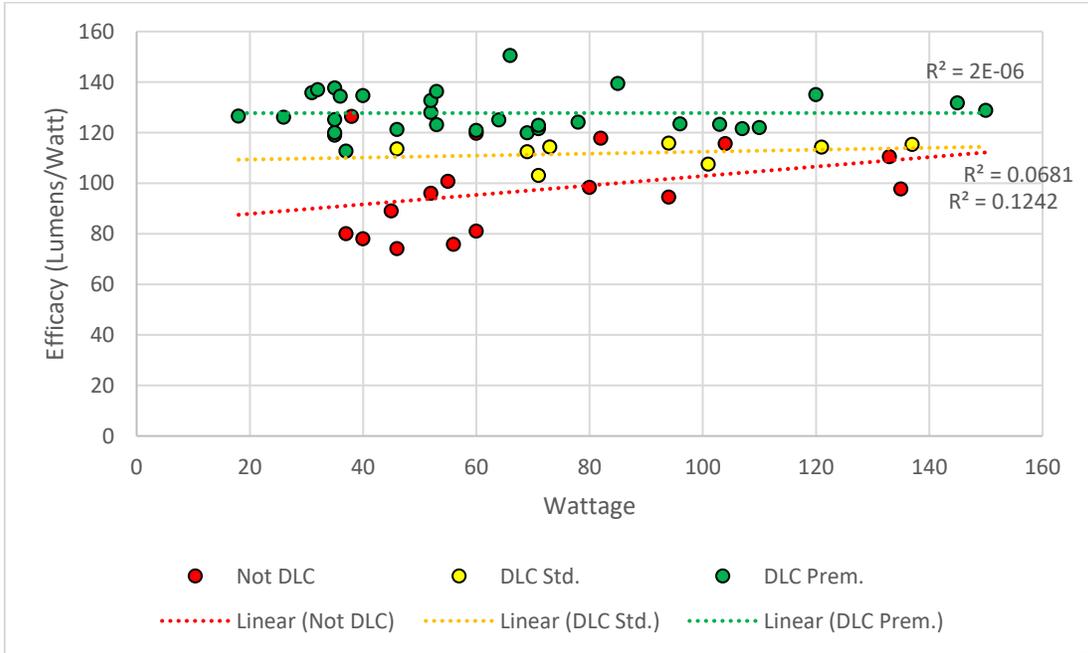
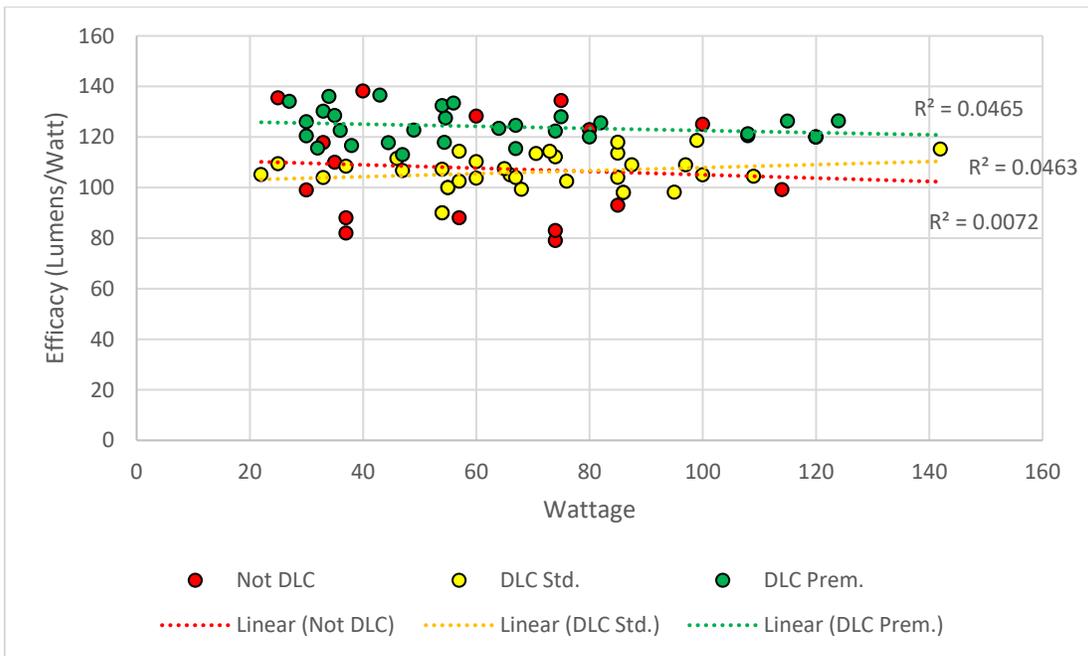


Figure 35: Efficacy versus Wattage: Parking Garage



7.6.5 Projected Fixture Efficacy by Product Type and DLC Classification

The following tables provide the projected ISP efficacy for the outdoor lighting fixtures, by product type and DLC classification and DLC output grouping.

Table 74: LED Efficacy Projections for 2019

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Swimming Pool
Low Output <5k	112	113	107	110	56	121	112	49
Mid Output 5k-10k	111	114	114	117	N/A	119	115	N/A
High Output 10k-30k	116	119	158	118	N/A	121	120	N/A
Very High Output 30k and up	137	120	N/A	126	N/A	N/A	N/A	N/A

Table 75: LED Efficacy Projections for 2020

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Swimming Pool
Low Output <5k	116	116	110	113	58	125	116	50
Mid Output 5k-10k	114	117	118	121	N/A	123	119	N/A
High Output 10k-30k	120	123	164	122	N/A	125	123	N/A
Very High Output 30k and up	142	124	N/A	130	N/A	N/A	N/A	N/A

Table 76: LED Efficacy Projections for 2021

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Swimming Pool
Low Output <5k	120	120	114	117	60	129	119	52
Mid Output 5k-10k	118	121	122	125	N/A	127	123	N/A
High Output 10k-30k	124	127	169	126	N/A	129	128	N/A
Very High Output 30k and up	147	128	N/A	134	N/A	N/A	N/A	N/A

Table 77: LED Efficacy Projections for 2022

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Swimming Pool
Low Output <5k	124	124	117	121	62	133	123	54
Mid Output 5k-10k	122	125	126	129	N/A	132	127	N/A
High Output 10k-30k	128	131	175	130	N/A	134	132	N/A
Very High Output 30k and up	151	132	N/A	139	N/A	N/A	N/A	N/A

Table 78: LED Efficacy Projections for 2023

Product Category	Streetlight	Pole Mount	Wall Mount	Floodlight	Bollard	Fuel Canopy	Parking Garage	Swimming Pool
Low Output <5k	128	128	121	125	64	138	127	55
Mid Output 5k-10k	126	129	130	133	N/A	136	131	N/A
High Output 10k-30k	133	136	180	135	N/A	138	136	N/A
Very High Output 30k and up	156	136	N/A	143	N/A	N/A	N/A	N/A

7.7 Literature Review Estimates of Installed Fixtures

This section provides results from the literature of installed (a.k.a. existing) stock.

7.7.1 Commercial Building Stock Assessment (NEEA 2016)

This report provides the findings of the 2014 Commercial Building Stock Assessment (CBSA) for the Pacific Northwest. The study includes audit results of 1,380 commercial buildings, which is a compilation of survey data collected from the 859 buildings sampled as part of the 2014 Core CBSA, and 521 additional sites surveyed as part of CBSA Oversample studies performed at the request of Bonneville Power Administration (BPA), Puget Sound Energy (PSE), Seattle City Light (SCL), and Snohomish County PUD (SnoPUD). The various building types include Assembly, Food Service, Grocery, Hospitals, Lodging, Office, Residential Care, Retail, Schools, Universities, Warehouse, and other buildings. Data was primarily collected in 2014 and NEEA published the study in Dec. 2014.

For exterior lighting – referred to as outdoor lighting in the NEEA report – the various technologies include linear fluorescents T8/T5 lamps and T12 lamps, CFLs, incandescent lamps, HID lamps, LEDs, and other lamps. This report also includes a classification based on building use types. The following figures show the distribution of outdoor lighting power based on technology for several categories: Commercial & Industrial – which includes building facades, exterior sales, signage, sporting fields and other lighting; walkways and area-lighting, which includes many pole-mounted fixtures; parking lots; and parking garages.

Figure 36: Outdoor Lighting Power by Technology: Commercial and Industrial (NEEA 2016)

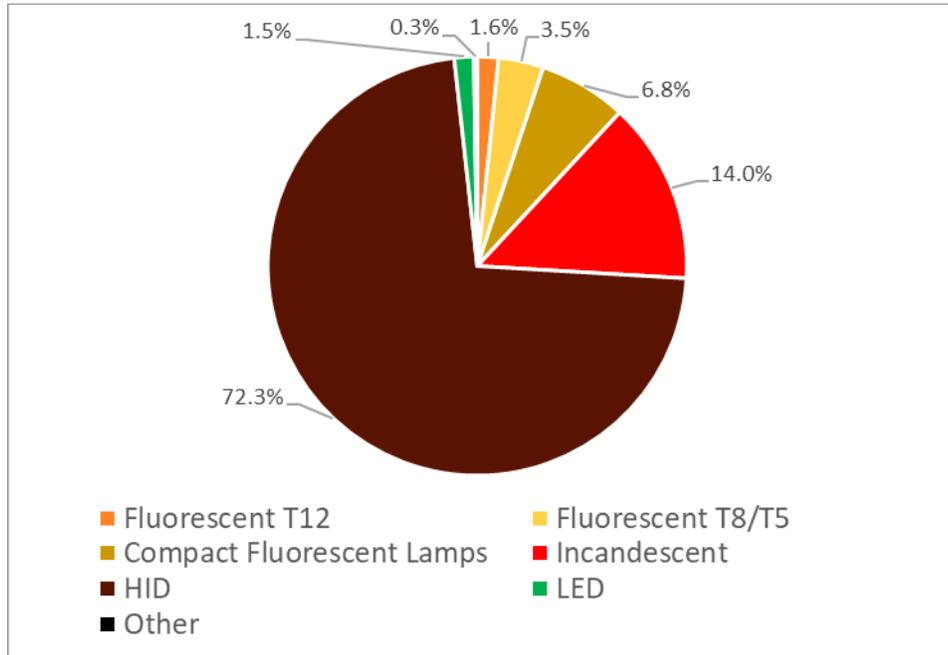


Figure 37: Outdoor Lighting Power by Technology – Walkways / Area Lighting (NEEA 2016)

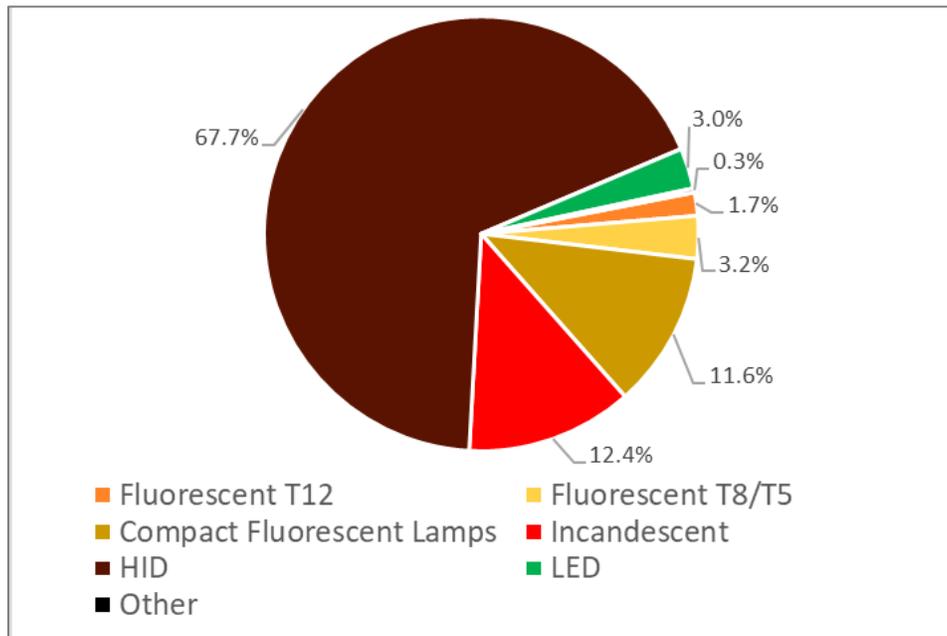


Figure 38: Outdoor Lighting Power by Technology – Parking Lots (NEEA 2016)

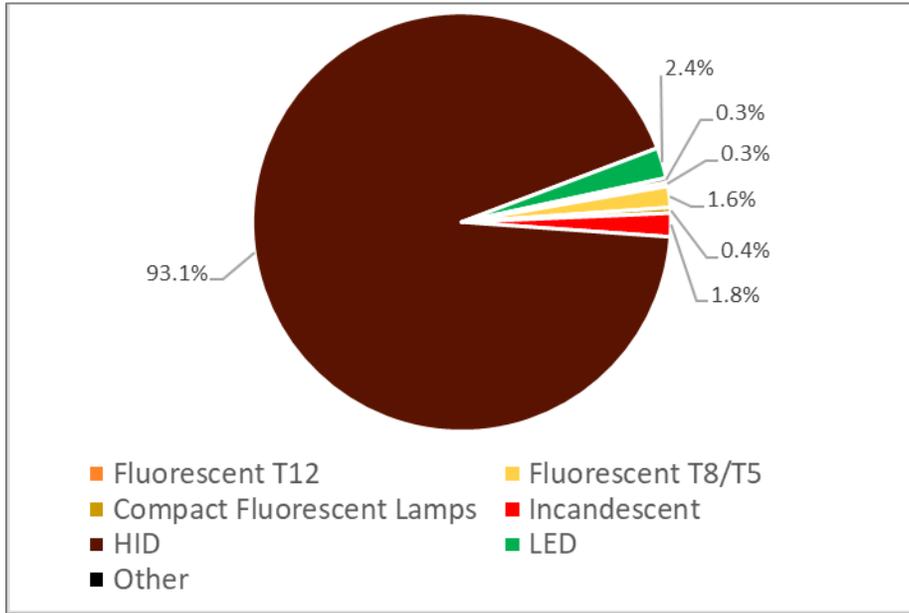
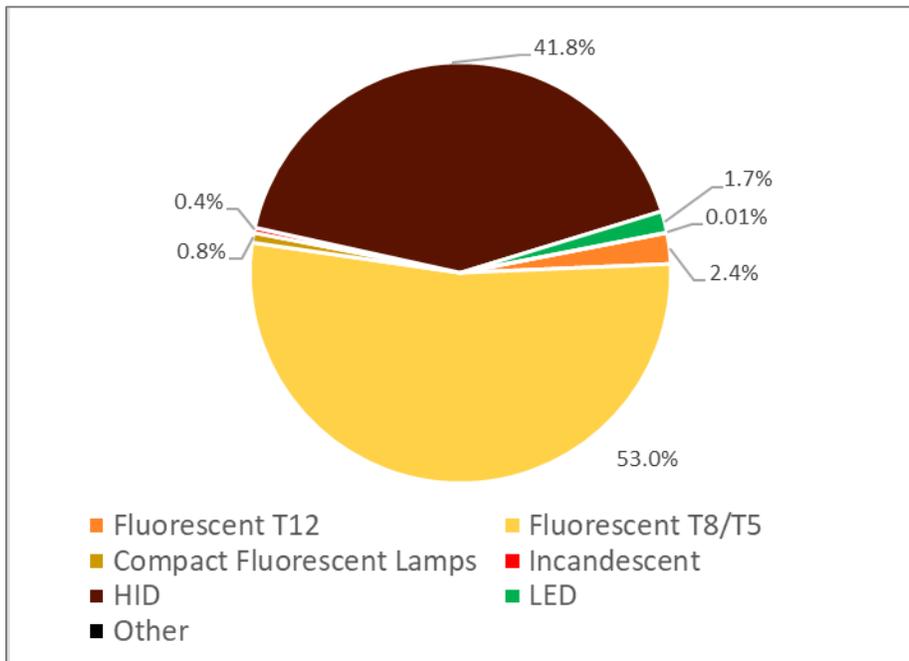


Figure 39: Outdoor Lighting Power by Technology – Parking Garage (NEEA 2016)



The report findings show that HID uses the majority of the lighting power for all categories except parking garage, which are dominated by linear fluorescent and HID lighting.

7.7.2 California Commercial Saturation Survey (Itron 2014)

The California Commercial Saturation Survey (CSS) study was designed to collect baseline energy consumption data at commercial buildings in California. The research objective was to determine the baseline equipment in commercial businesses in the electric service territories of the California electric IOUs. The CSS data collection was conducted from November 2011 through May 2013 and published in 2014.

The CSS study for outdoor lighting covers information from 983 on-site visits with businesses in eight commercial business types: Food/Liquor stores, Health/Medical Clinics, Miscellaneous businesses, Offices, Restaurants, Retail, Schools, and Warehouses. The data set includes parking lots, parking garages, wall mounted lighting, and outside spaces at the site of a business (e.g., patios). Outdoor lighting excludes all advertising displays. The various lighting technologies identified in this report include linear fluorescent, CFL, incandescent, halogen, LED, HID, and other lighting.

CSS presents data according to whether the customer had participated in a lighting energy efficiency (EE) program or not. The following figures show the distribution of lamps for lighting technologies for EE Lighting Program participants and non-participants.

Figure 40: Outdoor Lighting: Distribution of Lamps by Technology (EE Lighting Non-Participant)

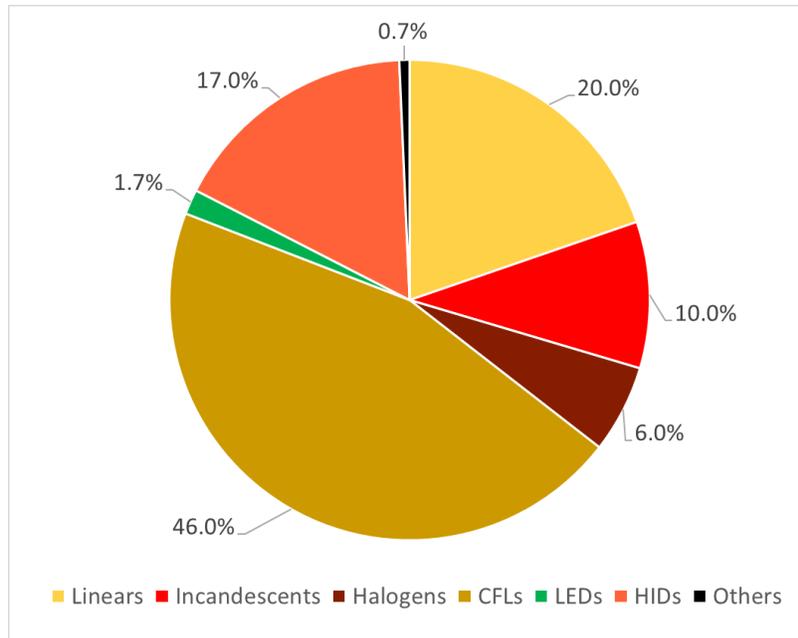
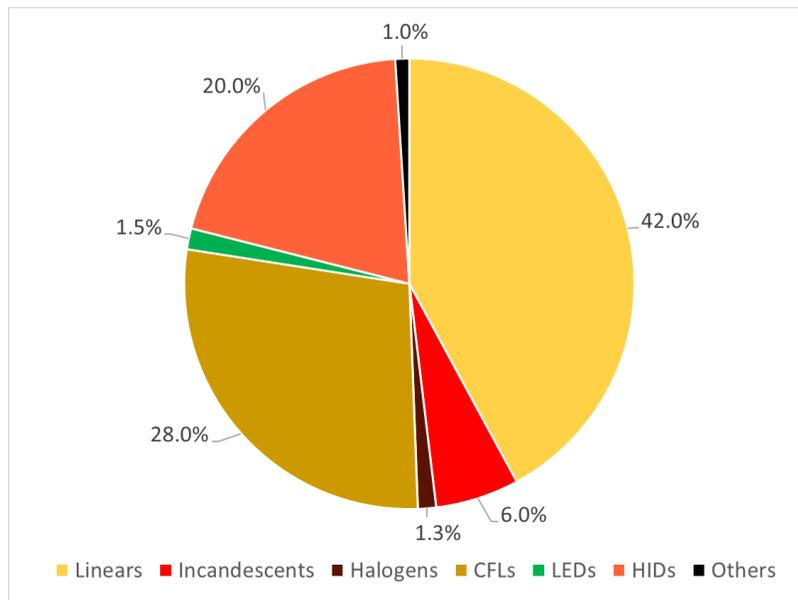


Figure 41: Outdoor Lighting: Distribution of Lamps by Technology (EE Lighting Participant)



For both program participants and non-participants, linear fluorescents and CFLs dominate the existing stock.

7.7.3 US Lighting Market Characterizations (DOE 2017a)

The US Lighting Market Characterization (LMC) was published by the U.S. Department of Energy’s (DOE’s) Solid-State Lighting (SSL) Program. This report provides estimates of the installed stock, energy use, and lumen production of all general illumination lighting products operating in the U.S.

The outdoor lighting accounts for lamps and luminaires (which are essentially the same as fixtures) installed on the exterior of commercial or industrial buildings. The data set also includes all the lighting not installed inside buildings, which can be classified based on application such as railways, airfields, billboards, communication towers, parking, roadways, sports fields, and traffic signals. The data analyzed in this report was collected from 2009 – 2017, which includes on-site data for 404 commercial and industrial buildings. Inputs for the remaining outdoor applications were collected through a wide variety of sources, including interviews with government and industry representatives, trade association surveys and datasets, and web research. The following figures present the installed stock parking lots and garages (grouped together), and roadways.

Figure 42: Estimated Inventory of Lamps by Technology - Parking Lots & Garages (DOE 2017a)

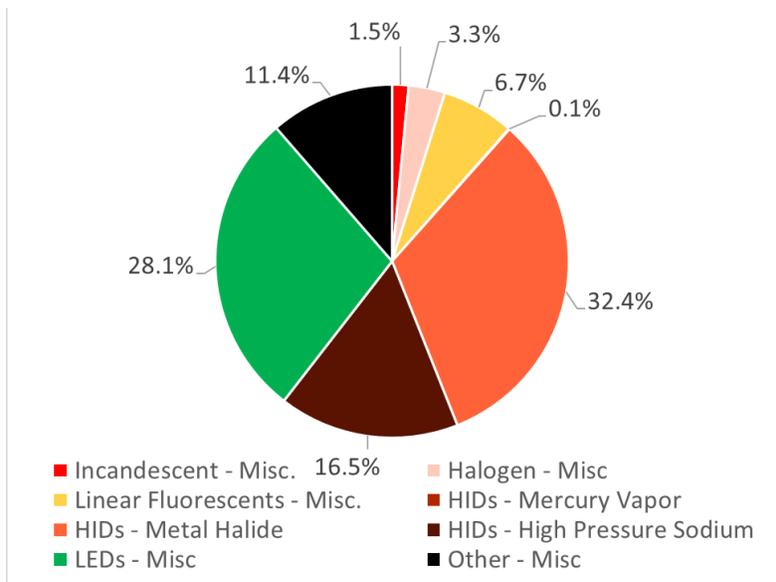
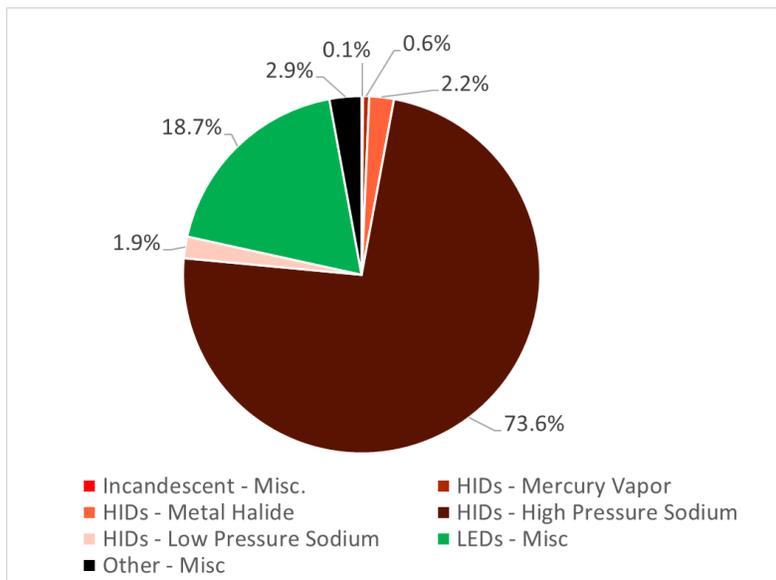


Figure 43: Estimated Inventory of Lamps by Technology – Roadways (DOE 2017a)

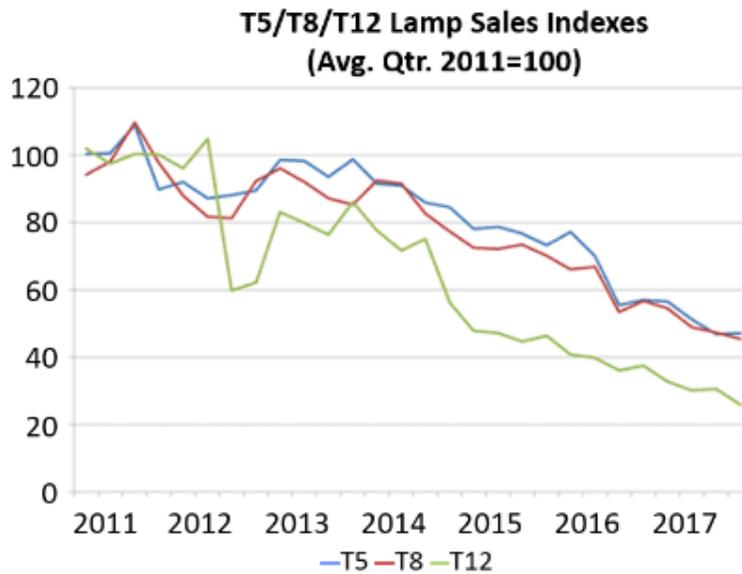


HID technologies – including HPS and metal halide – dominate both areas. The parking areas have a larger fraction of LEDs, but also LED comprise a sizeable fraction of roadways.

7.8 NEMA Lamp Indices (2011-2018)

NEMA provides sales indices³⁸ – indexed to 2011 sales, and lamp shipments for several lamp categories. The following two figure present lamp sale indices for linear fluorescent lamps, and the fraction of linear fluorescent and tubular LED (TLED) lamp shipments by technology.

Figure 44: Lamp Sales Indices for Linear Fluorescent Lamps (NEMA)



³⁸ <https://www.nema.org/Intelligence/Pages/Lamp-Indices.aspx>

Figure 45: Linear Fluorescent and Tubular LED (TLED) Shipments – Percent by Technology (NEMA)

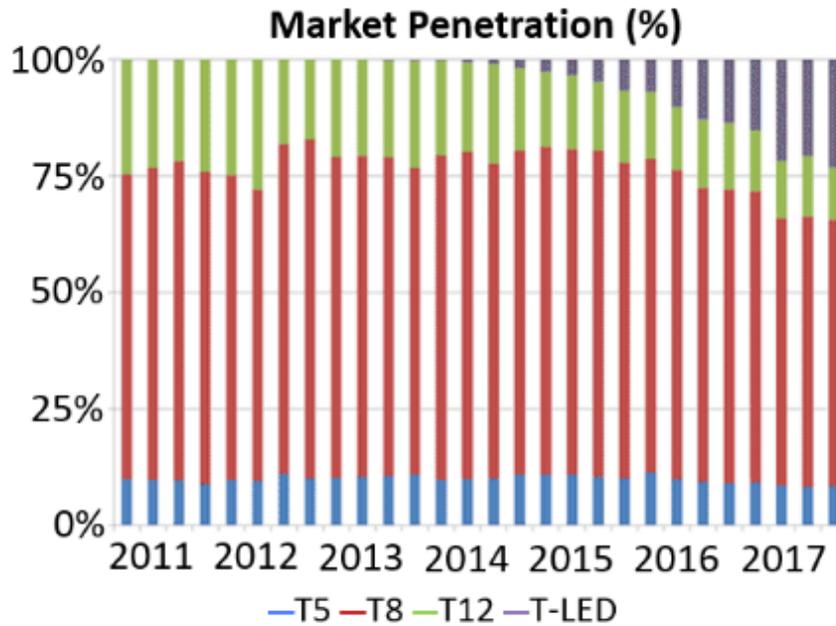
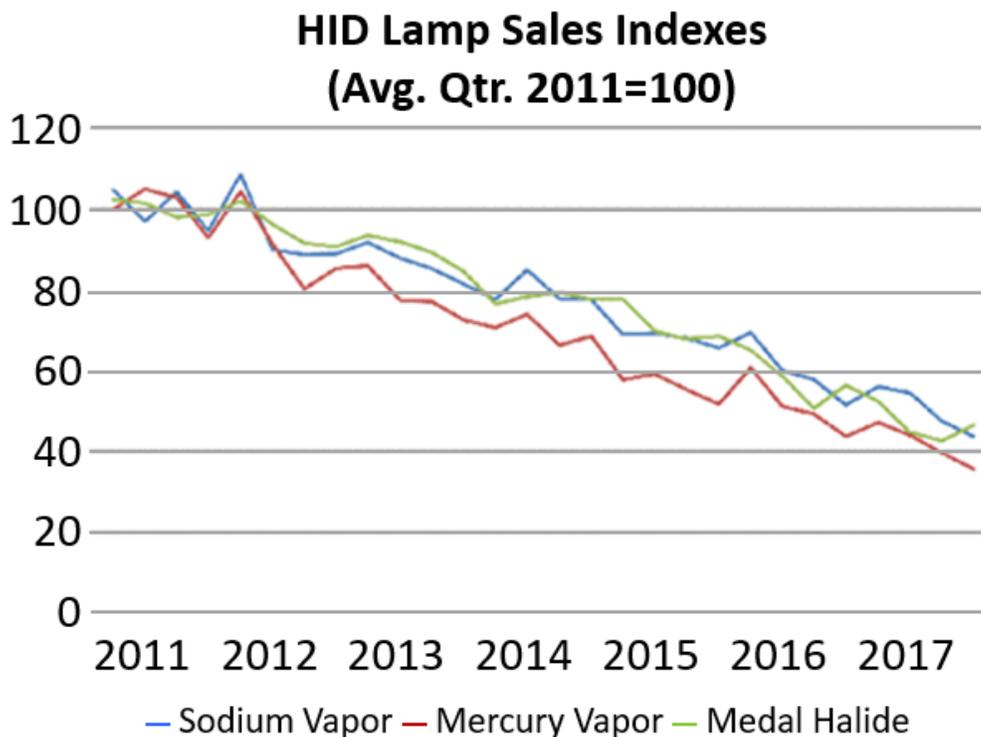


Figure 46 shows sales indices for high intensity discharge (HID) lamps. Overall, HID lamp sales have decreased by slightly more than 50% for sodium vapor and metal halide, and by 60% for mercury vapor. NEMA does not provide shipment penetrations that include comparable LED products for this lamp category.

Figure 46: HID Lamp Sale Indices (NEMA)



7.9 Survey Guide



436 14th Street
Suite 1020
Oakland, CA 94612

510.400.5374 PHONE
510.451.7002 FAX

MEMORANDUM

To: Reggie Wilkins (SCE), Doreen Caruth (PG&E), Esther Chen (SDG&E), and IOU collaborators

From: Michael Mutmansky, Marian Goebes, and Cathy Chappell (TRC)

Date: July 24, 2018

EXTERIOR LIGHTING BASELINE STANDARD PRACTICE AND WORKPAPER SUPPORT STUDY: REVISED SURVEY GUIDE

Description of Guide and Survey Administration

As part of the Exterior Lighting Baseline Standard Practice and Workpaper Support Study conducted for the California electric Investor Owned Utilities (IOUs), led by Southern California Edison – SCE, TRC will conduct telephone surveys with the following exterior lighting market actors: manufacturer representatives (“manufacturer reps”), maintenance contractors, and sales managers at lighting manufacturers.

- ◆ The primary goal of the surveys is to collect information on exterior lighting sales practices – i.e., to inform the replace-on-burn out (ROB)/ Normal Replacement (NR)/ Code Equivalent (CE)/ 2nd baseline for Early Retirement (ER).
- ◆ As secondary objectives, the surveys for manufacturer reps and maintenance contractors also include questions on the estimate of fixtures removed by technology (for early retirement projects), and barriers to early retirement.
- ◆ TRC expects that survey respondents will not be able to provide an estimate of luminaire sales (for manufacturers and manufacturer reps) or purchases (for contractors) as a percent by efficacy – e.g., could not accurately estimate what percentage are 110 lumens per watt (LPW), 120 LPW, 130 LPW, etc. Consequently, the survey guide asks for their estimates by DesignLights Consortium (DLC) listing: percentages by DLC premium, DLC standard, and non-DLC. In a separate data collection activity for this project, TRC will gather efficacy data for a range of products in the same product class, organizing data by DLC designation (i.e., efficacy range for DLC premium, DLC standard, and non-DLC). TRC will then combine survey responses (percent of sales by DLC listing) with product results (efficacy by DLC listing) to estimate market shares by efficacy, and a weighted average efficacy for each product class.

TRC will conduct survey via telephone and provide each respondent with a \$50 American Express gift card for completing the survey. TRC will track the respondents we contacted and the disposition for each (completed survey, no response, declined survey, etc.). This information will be kept internally but will not be included in the report documentation to maintain anonymity.

This memo provides draft language for the market actor surveys.

MANUFACTURER REPRESENTATIVE DRAFT SURVEY GUIDE

Italics text is for script language.

Blue text is for script directive for the surveyor.

Recruitment Contact and Screening

Hello Mr./Ms. {{{name}}},

I'm {{{name}}} and I'm calling from TRC Energy Services on behalf of {{{use the local utility of the person being surveyed}}} about an exterior lighting survey. We're offering a \$50 American Express gift card for participating in this 20-30 minute phone survey that will provide critical information for the utilities to develop energy efficiency rebate programs. All individual responses are anonymous. We'd be happy to send you a summary of study results once it is published.

S1: I'll primarily be asking about percentages of exterior luminaires that you have sold in the past 12 months in California, broken down by light source technology. Are you knowledgeable of your company office's sales of exterior luminaires in California?

[Response]

Yes →

When would you like to schedule a 20-30 minute time to talk?

{{{Identify a time. If they would prefer to speak right then, move forward with survey. The preference is to schedule the survey for later, so they have time to think through some of the questions}}}

Thanks, I'll send you a calendar invitation for {{{time and date}}}. It will include the topics we'll cover in the survey, to help you start thinking about responses. What email address should I use for the calendar invitation?

No →

Who is a better person at you company to talk to about exterior luminaire sales?

{{{Get a name for the person if there is a referral and thank the respondent again. Document the contact in the tracking spreadsheet and move to next contact}}}

Thank you for your willingness to participate in this important survey.

{{{If they cannot accept a gift card, provide them with an option to donate the \$50 to a charity. Respondents can choose from St. Jude's Children's Hospital, United Way, or Doctors without Borders}}}

Q#1. To start, please tell me your title.

{{{Record responses. This will also be used as a second screener question. If they do not appear to be involved in exterior luminaire sales, request the name of someone at their company that is and thank them for their time}}}

Section A: Definitions

Surveyor Notes:

- *Several of these product categories have a correlating category in the Design Lights Consortium (DLC) Qualified Products List (QPL). Some, like the Fuel Canopy and Parking Garage categories have specific light output limits in the QPL that make the definition very specific so that a typical product that may be mounted in a similar manner may not truly meet the category definition. We are using the DLC QPL definitions for this discussion.*
- *If they ask for clarification during the survey, here are definitions for new construction, retrofits, and renovations:*
 - *New Construction – Projects that create a new building or additions to an existing building that add square footage or similarly adding new hardscape to a property*
 - *Retrofits – Projects that are primarily intended to replace or update existing exterior lighting systems with new lighting equipment*
 - *Renovations – Projects that involve renewal of the exterior lighting system, typically motivated by changes in use of the space, or by the need to update the space aesthetically}}*

Section B: Luminaire sales Information

For this survey, we are only interested in product sales in California within the past 12 months. We will also discuss some future projections for California towards the end. For all questions, please answer in the context of your company’s office.

Q#2: We’re studying nine luminaire product categories. For each, I’ll ask if your company sells it. {{{Offer Yes, No, or Occasionally for each}}}

	Yes	No	Occasionally
1. Street Lighting is strictly used for lighting streets and roads and is normally purchased for municipal installations. Does your office sell these?			
2. Pole-Mounted includes traditional parking lot pole-mounted, and decorative pedestrian products.			
3. Wall-Mounted includes wal-paks, sconces, and entry lights.			
4. Flood & Spot Lighting is primarily for products intended for aiming towards a subject or area.			
5. Bollards are primarily low height (below 4 foot) products that are ground mounted and light paths and paved areas.			
6. Fuel Canopies are typically designed for gas station canopy applications and may be surface mounted or recessed into the canopy.			
7. Parking Garage luminaires are used to light parking garages, including linear and shoebox style fixtures.			
8. Pool Lighting is exclusively for mounting underwater in pools or other water features.			
9. Street Sign Lighting is used to illuminate street names, and typically hangs from the signal pole arms.			

Section C: Purchased Fixtures

We are focusing on new construction and retrofit/renovation work, not luminaire replacements for damaged or failed products. Please remember, this is for luminaires sold in the California market. Also, my questions about percentages refer to percentage by numbers of luminaires, not percentage by dollars.

Q#3 Of the following, please provide an approximate breakdown of the percentage of your sales that go to each construction type:

Only discuss the products they have indicated they maintain. Skip the others. Left to right, the total should be 100%, so you only need to ask about one value to determine both values for each product category

	new construction (%)	retrofits & renovations (%)
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Q#4 For all exterior luminaire sales in California, what is the overall breakdown of your total exterior lighting sales percentages based on the following light source technologies?

Start with LED, as that should be the highest percentage. If they start to overshoot the 100% amount by over 20%, ask them to re-evaluate the largest ones based on the context of the answers they made for the smaller shares

	Percentage
LED	
Metal Halide	
HPS	
LPS	
Linear FL	
CFL	
Other	

Q#5 You stated that LEDs represent approximately *Q4 for LEDs* of the total sales of exterior luminaires. With that in mind, would you estimate that the LED percentage is higher, lower, or the same for each product category? If different, please provide an approximate percentage for the LED sales in that product category.

Product Category	Lower or Higher?	New %

street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
Bollard		
fuel canopy		
parking garage		
pool lighting street sign lighting		

Q#6. We are trying to understand if there are any differences in practices for new construction compared with retrofits and renovations. You stated that LEDs represent approximately *{{{value reported in Q4 for LEDs}}}* of your total purchases of exterior luminaires in California in the past 12 months.

- a. Is the percent of LED installations lower, higher, or about the same for New Construction, by which I mean projects that create a new building or additions to an existing building? Is the percent of LED installations lower, higher, or about the same as *{{{value reported in Q4 for LEDs}}}*?

Lower	Higher	Same	New value

- b. What about for Retrofits and Renovations, by which I mean projects that replace an existing exterior lighting system, to update it or because of a change in space use or occupant? Remember we are NOT talking about lamp replacements due to burn out. Is the percent of LED installations lower, higher, or about the same as *{{{value reported in Q4 for LEDs}}}*?

Lower	Higher	Same	New value

Q#7 For which product categories do you see a significant difference in the percent of purchases that are LEDs between new construction compared with retrofits and renovations? *{{{value reported in Q4 for LEDs}}}*

Product category	Difference in Percent	NC or Retrofits has higher LED percent?	About how much higher (%)
street lighting			
pole-mounted			
wall-mounted			
flood & spot lighting			
bollard			
fuel canopy			
parking garage			

pool lighting			
street sign lighting			

Q#8 In this next question, we are interested in purchasing information based on customer type, by which I mean market segment (such as schools, retail, grocery, and other business types), and in some cases, customer size.

For each of the following customer types, would you say the percent of exterior LED luminaires is higher, lower, or about the same as the *LED value in Q#4*?

	Higher	Lower	Don't Serve
1. Large Retail (like big box store)			
2. Small Retail			
3. Large Grocery (like supermarket)			
4. Small Grocery (like a local grocer or corner store)			
5. Large Offices (>25,000 sf)			
6. Small Offices (<25,000 sf)			
7. Restaurant			
8. K-12 school			
9. College or university			
10. Multifamily			
11. Hospital and large healthcare buildings			
12. Municipal projects			
Are there any other types of customers that you do significant sales for, that we didn't list? (specify):			

Section D: Efficacy

Thank you. We'll now shift our focus to a few questions on luminaire efficacy. Recall that we're only discussing sales in California.

Q#9 Focusing on LED luminaires let's discuss breakdowns by DesignLights Consortium (DLC) ratings for the LED products you sell. For New Construction projects, what percentage of your exterior LED luminaires sold are DLC Listed?

	Percent
DLC Premium	
DLC Standard	
not DLC listed	

Q#10 For Retrofit and Renovation work, what percentage of your exterior LEDs sold are DLC Listed?

	Percent

DLC Premium	
DLC Standard	
not DLC listed	

Q#11 Does this vary by product category? If so, for *new Construction or Retrofit /Renovation – whichever they do MORE of, or combine for all exterior luminaires*, how does DLC Premium and Standard listing percentages differ (higher or lower) for these product categories?

Leave blank if they are the same values as in Q#9 or Q#10 above

Product Category	DLC premium (%)	DLC standard (%)
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
Bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Q#12 Do you sell LED exterior lighting products that DO NOT have the DLC QPL listing but do meet or exceed the efficacy requirements of the QPL? If so, what percentage of the total exterior luminaires that you sell are not QPL listed but would likely meet the Premium or Standard listing levels?

QPL = qualified products listing. This table should total no more than the value in Q#10 for the “Not DLC Listed” result, but it doesn’t need to equal that value. Some products could be not listed AND not able to meet the efficacy requirements

	Percent
would meet DLC premium	
would meet DLC standard	

Q12b. Now I’m going to ask about efficacy more directly. For each product category that you manufacturer, can you please give me an estimate of your LED sales by efficacy bin? The bins are <90 Lumens per watt (Lm/W), 90-100 Lm/W, 100-110 Lm/W, 110-120 Lm/W, and >120 Lm/W.

	<90	90-100	100-110	110-120	>120
street lighting					
pole-mounted					
wall-mounted					
flood & spot lighting					

bollard					
fuel canopy					
parking garage					
pool lighting					
street sign lighting					

Section E: Future Projections

Q#13 So far, we’ve been discussing recent product sales. Let’s talk briefly about projections. You indicated that LEDs comprised approximately *use the LED value from Q#4 above* of your exterior luminaire sales for the past 12 months. In the next 2 years, do you expect the percentage of LEDs to increase, decrease, or stay about the same for your exterior luminaire sales for New Construction? If different, please provide an approximate percentage.

If they say LEDs are >=95% of current sales, just ask for total exterior luminaire projections in 2 years and 5 years, don’t ask by NC vs. retrofits

Q#14 Approximately what percentage of your exterior luminaire sales do you expect to be LEDs in 5 years, for New Construction?

Q#15 Similarly for Retrofits and Renovations: You indicated that LEDs comprised approximately *use value from Q#4 above* of your total exterior luminaire sales for the past 12 months. In the next 2 years, do you expect the percentage of LEDs to increase, decrease, or stay about the same for your exterior luminaire sales for Retrofits and Renovations? If different, please provide an approximate percentage.

Q#16 Approximately what percentage of your exterior luminaire sales do you expect to be LEDs in 5 years, for Retrofits and Renovations?

Q#17 Thinking back to the product categories we discussed, do you anticipate that any product category will be lower or higher than the *use value from Q#16 above* percent you estimated for Retrofits and Renovations in 5 years? *Only ask for product categories that they reported they sell*

	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
bollard		
fuel canopy		
parking garage		
pool lighting street sign lighting		

Section F: Existing fixtures that are replaced

We are almost near the end of the survey. I'd like to ask about existing fixtures that have been replaced or retrofitted in California in the past 12 months.

Q#18 Can you provide a breakdown of the light source technologies (by percentage) that you see being replaced in exterior lighting systems with the new lighting products you sell?

{{{The total across per row should be approximately 100%. Focus on getting the top two or so values. If total values exceed 120%, ask them to reconsider earlier responses}}}

	LED	Metal Halide	HPS	LPS	Linear Fluorescent	CFL	Other
street lighting							
pole-mounted							
wall-mounted							
flood & spot lighting							
bollard							
fuel canopy							
parking garage							
pool lighting							
street sign lighting							

Q#19 My next question is about barriers to retrofits. For your customers that continue to just replace failed luminaires, one-off as they fail, why do they not implement a retrofit?

Section G: Finish

Q#20 Finally, can you please estimate the total number of exterior luminaires your company office has sold or claimed sales credit for in California in the past 12 months? Would you say it's:

- a. <10,000
- b. 10,000-50,000
- c. 50,000-100,000
- d. 100,000-250,000
- e. 250,000-500,000
- f. >500,000

Thank you for your participation in this survey.

{{{If they provide estimate in \$ value, record that, but still ask them to estimate number of luminaires. If they're willing to provide an open-ended estimate – not multiple choice – record that}}}

Q#21 Your answers are important to us, and we know that your time is valuable. In recognition of this, we'd like to send you a gift card in the amount of \$50. Can you provide a mailing address to send this to? It will take about 6 weeks to arrive.

MEMORANDUM (continued)

To: Reggie Wilkins (SCE) and IOU collaborators

July 12, 2018

Re: Revised Survey Guide for the Exterior Lighting Baseline Standard Practice and Workpaper Support Study

Q#22 We'd also like to follow up with survey results once we have that completed. Would you like us to send you an email with the report link when it is completed?

{{{If yes, ask for email address if you don't have it already}}}

Q#23 Can you please recommend a colleague in another office (so serving another region of California) that we could survey? If so, please provide their email address.

Note that the California IOUs are conducting another study for interior sales, and you may be contacted for a survey for that study.

{{{If they comment that they either would like to participate, or would not like to participate, note this and share with PG&E for the Navigant study of interior fixtures}}}

Thank you again for your help. If you have any questions on this survey, please feel free to contact me or my colleagues here at TRC Energy Services at {{{phone number}}}.

MAINTENANCE CONTRACTOR DRAFT SURVEY GUIDE

Italics text is for script language.

Blue text is for script directive for the surveyor.

Recruitment Contact and Screening

Cold Calling:

Hello Mr./Ms. {{{name}}},

I'm {{{name}}} and I'm calling from TRC Energy Services on behalf of {{{use the local utility of the person being surveyed}}} about an exterior lighting survey to inform utility incentive programs. We're offering a \$50 American Express gift card for maintenance contractors with knowledge of exterior lighting purchases to participate in a 15-20 minute phone survey. All individual responses are anonymous. Would you be interested in hearing more about the survey?

Follow Up on Email:

I am {{{name}}} from TRC Solutions.

I'm following up on my email for a phone survey about exterior luminaires for the California utilities. The survey takes 15-20 min. and we provide a \$50 gift card in recognition of your time.

Would you be willing to participate in the survey this week or next?

(Pause and see what they say)

I'll be asking for your best estimates by %, of your exterior luminaire installations by technology, for example, % LEDs, % metal halides, etc. Just confirming: are you the right person at your company for this survey? If not, is there a project manager or crew manager I can speak with? (Job boss=good: purchasing manager = not good)

Phone call with no prior email with no contact person identified

I am {{{name}}} and I'm conducting a phone survey on exterior fixtures on behalf of the California utilities. The survey takes 15-20 min. and we provide a \$50 gift card for completing it. The survey asks for your estimates of your exterior fixture installations by technology, for example, % that are LEDs. Could you please direct me to the best person at your company to complete the survey, such as a project manager or crew manager?

(Pause and see what they say)

(Job boss=good: purchasing manager = not good)

Voicemail message:

Hi, this is {{{name}}} from TRC Solutions.

I'm following up on my email for a phone survey regarding exterior luminaires for the California utilities.

The survey takes 15-20 minutes and we'd provide a \$50 gift card.

If you can participate in the survey this week or next, please email me or call me at: 510-401-1512.

Thank you

S1: I'll primarily be asking about percentages of exterior luminaires that your office has purchased in the past 12 months in California, broken down by light source technology, such as LED, high pressure sodium, metal halide, etc. Are you knowledgeable of your company office's installations of exterior luminaires in California?

[Response]

Yes →

When would you like to schedule a 15-20 minute time to talk?

{{{Identify a time. If they would prefer to speak right then, move forward with survey. The preference is to schedule the survey for later, so they have time to think through some of the questions}}}

Thanks, I'll send you a calendar invitation for {{{time and date}}}. It will include the topics we'll cover in the survey, to help you start thinking about responses. What email address should I use for the calendar invitation?

No →

Who a better person at you company to talk to about exterior luminaire purchases?

{{{Get a name for the person if there is a referral and thank the respondent again. Document the contact in the tracking spreadsheet and move to next contact}}}

Thank you for your willingness to participate in this important survey.

{{{If they cannot accept a gift card, provide them with an option to donate the \$50 to a charity. Respondents can choose from St. Jude's Children's Hospital, United Way, or Doctors without Borders}}}

Section A: Definitions

Surveyor Notes:

- *Several of these product categories have a correlating category in the Design Lights Consortium (DLC) Qualified Products List (QPL). Some, like the Fuel Canopy and Parking Garage categories have specific light output limits in the QPL that make the definition very specific so that a typical product that may be mounted in a similar manner may not truly meet the category definition. We are using the DLC QPL definitions for this discussion.*
- *If they ask for clarification during the survey, here are definitions for new construction, retrofits, renovations, and replacements:*
 - *New Construction – Projects that create a new building or additions to an existing building that add square footage or similarly adding new hardscape to a property.*
 - *Retrofits and Renovations.*
 - o *Retrofits are projects that are primarily intended to replace or update existing exterior lighting systems with new lighting equipment.*
 - o *Renovations – Projects that involve renewal of the exterior lighting system, typically motivated by changes in use of the space, or by the need to update the space aesthetically}}}*
 - *Replacements – replacing just lamps or luminaires that have failed or burned out*

Section B: Luminaire Purchases Information

Q1. To start, please tell me your title.

Record responses. This will also be used as a second screener question. If they do not appear to be involved in exterior luminaire installations or purchases, request the name of someone at their company that is and thank them for their time

For this survey, we are only interested in product installations in California within the past 12 months. We will also discuss some future projections for California towards the end. For all questions, please answer in the context of your company's experience within the office that you work. My questions about percentages refer to percentage by numbers of luminaires, not percentage by dollars.

Q#2 Which product categories does your company office maintain for your client base? Please answer yes, no, or occasionally for each.

	Yes	No	Occasionally
1. Street Lighting for lighting streets and roads and is normally purchased for municipal installations. Does your office sell these?			
2. Pole-Mounted, this includes traditional parking lot pole-mounted, and decorative pedestrian products.			
3. Wall-Mounted includes wal-paks, sconces, and entry lights.			
4. Flood & Spot Lighting for aiming towards a subject or area.			
5. Bollards are primarily below 4 feet and are ground mounted and light paths and paved areas.			
6. Fuel Canopies are typically for gas station canopy applications. <i>If needed: they may be surface mounted or recessed into the canopy</i>			
7. Parking Garage luminaires , such as linear and shoebox style fixtures.			
8. Pool Lighting for mounting underwater in pools or other water features.			
9. Street Sign Lighting to illuminate street names, and typically hangs from the signal pole arms.			

Section C: Purchased Fixtures

Q#3: Please provide an approximate breakdown of the percentage of your exterior luminaire installations in California in the past 12 months that go to:

- New construction** – meaning new buildings or additions, vs.
- Retrofits**– renovations, or updates to all exterior luminaires in an area, vs.
- Replacements** – meaning replacements of failed luminaires

Only discuss the products they have indicated they represent. Skip the others. If the total is >100% across a row, don't worry about unless total exceeds 120% - then ask them to reconsider earlier estimate

	new construction (%)	retrofits (%)	Replacements due to failure (%)

street lighting			
pole-mounted			
wall-mounted			
flood & spot lighting			
bollard			
fuel canopy			
parking garage			
pool lighting			
street sign lighting			

For the remainder of this survey, please provide responses for new construction and retrofits. Toward the end of the survey, I'll ask a few questions about replacement, but for now, don't include replacements in your responses.

Q#4 What is the overall breakdown of your total exterior lighting installation, by percent, based on the following technologies?

Start with LED, as that should be the highest percentage. Allow them to tell you a number and fill it in. As you go down the list, they may re-think the LED number, so be flexible to adjust that as they make corrections. If they don't and you start to overshoot the 100% amount by over 20%, ask them to re-evaluate the largest ones based on the context of the answers they made for the smaller shares}}

	Percentage
LED	
Metal Halide	
HPS	
LPS	
Linear FL	
CFL	
Other	

Q#5 You just stated that LEDs represent approximately *insert the value reported in the table in Q4 for LEDs}}* of installations. With that in mind, would you estimate that the LED percentage is higher, lower, or the same for each product category? If different, please provide an approximate percentage for the LED purchases in that product category.

If they say 100% LEDs in Q4, rephrase as: Are there any product categories where your exterior luminaire installations are NOT 100%?

Product Category	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		

bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Q#6 In this next question, we are interested in purchasing information based on customer type, by which I mean market segment (such as schools, retail, grocery, and other business types). First off, which types of customers do you typically serve for exterior lighting?

Do you primarily serve large customers (>25,000 sf) or small customers (<25,000 sf)?

	Serve
1. Large Retail (like big box store)	
2. Small Retail	
3. Large Grocery (like supermarket)	
4. Small Grocery (like a local grocer)	
5. Large Offices (>25,000 sf)	
6. Small Offices (<25,000 sf)	
7. Restaurant	
8. K-12 school	
9. College or university	
10. Multifamily	
11. Hospital and large healthcare buildings	
12. Municipal projects	
other (specify):	

Q6a. For any of those customer types, would you say the percent of exterior luminaire installations that are LEDs is significantly higher or lower than [{{{value reported in Q4 for LEDs}}}](#)?

Section D: Efficacy

We'll now shift our focus to a few questions on luminaire efficacy. Recall that we're only discussing installations in California.

Q#7 Focusing on LED luminaires let's discuss breakdowns by DesignLights Consortium (DLC) Qualified Products Listing for the LED products you install. For New Construction projects, what percentage of your exterior LED luminaires are DLC Listed?

	Percent
DLC Premium	

DLC Standard	
not DLC listed	

If they can only tell you DLC vs not DLC, capture that and note that.

If they say they're only sure about DLC listing for XX% of products, note that too.

Q#8 For Retrofit work, what percentage of your exterior LEDs purchased are DLC Listed?

	Percent
DLC Premium	
DLC Standard	
not DLC listed	

Q#9 Does this vary by product category? (PAUSE) If so, for Retrofit, how does DLC Premium and Standard listing percentages differ (higher or lower) for these product categories?

{{Leave blank if they are the same values as in Q#10 above}}

Product Category	DLC premium (%)	DLC standard (%)	Not DLC listed (%)
street lighting			
pole-mounted			
wall-mounted			
flood & spot lighting			
bollard			
fuel canopy			
parking garage			
pool lighting			
street sign lighting			

Q#10 Do you install LED exterior lighting products that DO NOT have the DLC listing but do meet or exceed the efficacy requirements of the QPL? If so, what percentage of the total exterior luminaires that you purchase are not QPL listed, but would likely meet the Premium or Standard listing levels?

{{This table should total no more than the value in Q#10 for the "Not DLC Listed" result, but it doesn't need to equal that value. Some products could be not listed AND not able to meet the efficacy requirements}}

	Percent
would meet DLC premium	
would meet DLC standard	

Section E: Future Projections

[[If they say LEDs are >=95% of current installations, just ask for total exterior luminaire projections in 2 years and 5 years, don't ask by NC vs. retrofits]]

*Q#11 So far, we've been discussing recent product purchases, no we will be focusing on projections. You indicated that LEDs comprised approximately *[[LED value from Q#4]]* of your exterior luminaire installations in California for the past 12 months. In the next 2 years, do you expect the percentage of LEDs to increase, decrease, or stay about the same for your exterior luminaires?*

Q#12 Approximately what percentage of your exterior luminaire purchases do you expect to be LEDs in 5 years?

*Q#13 Thinking back to the product categories we discussed, do you anticipate that any product category will be lower or higher than the *[[use value from Q#12 above]]* percent you estimated in 5 years? *[[Only ask for product categories that they reported they maintain]]**

Q13Alt. If they're >=99% LEDs, are there any product categories that won't have 100% LED adoption?

Product Category	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Section F: Existing fixtures that are replaced

We are almost near the end of the survey. I'd like to ask about existing fixtures that have been replaced or retrofitted in California in the past 12 months. Remember that we are only discussing retrofit work, not replacements for damaged or failed products.

Q#14 Can you provide a breakdown of the light source technologies (by percentage) that you replaced in exterior lighting systems? The choices for each category are LED, metal halide, high pressure sodium, low pressure sodium, linear fluorescent, CFL, and other.

[[The total across per row should be approximately 100%. Focus on getting the top two or so values. If total values exceed 120%, ask them to reconsider earlier responses]]

	LED	Metal Halide	HPS	LPS	Linear Fluorescent	CFL	Other
street lighting							
pole-mounted							

wall-mounted							
flood & spot lighting							
bollard							
fuel canopy							
parking garage							
pool lighting							
street sign lighting							

Q#15. While my questions have focused on luminaire retrofits, I have a few questions about luminaire and lamp replacements. My first question is about barriers to retrofits. Why do some of your customers continue to just replace failed luminaires and lamps, one-off as they fail, instead of implementing a retrofit?

Q#16. My next question is about technologies installed for replacements. For your exterior luminaire and lamp replacements, what are they typically replaced with? Is it typically:

- The same technology that was removed, usually whatever was finished
- Something different – if so, what?

Q#20a. Finally, do you see any differences in whether your customers typically do retrofits, vs. replacements, for their exterior lighting systems, based on customer type? If needed: for example, do your small customers tend to do replacements instead of retrofits, or vice versa?

Section G: Finish

Q#17 Finally, can you please estimate the total number of exterior luminaires your company office has installed in California in the past 12 months? Would you say it's:

- a. <1,000
- b. 1,000 - 5,000
- c. 5,000 -10,000
- d. 10,000 - 50,000
- e. 50,000-100,000
- f. >100,000
- g. She says 10,000—50,000

If they ask you to clarify, this would be total luminaire installations – including new construction, retrofits and renovations, and luminaire replacement, but not lamp replacements

Thank you for your participation in this survey.

Q#18 We know your time is valuable, and we'd like to send you a gift card in the amount of \$50. Can you provide a mailing address to send this to? We will only use this address for sending the gift car. It will take about 6 weeks to reach you.

Q#19 Would you like us to send you an email with the report link when it is completed?

{{{If yes, ask for email address if you don't have it already}}}

MEMORANDUM (continued)

To: Reggie Wilkins (SCE) and IOU collaborators

July 12, 2018

Re: Revised Survey Guide for the Exterior Lighting Baseline Standard Practice and Workpaper Support Study

Q#20 Can you please recommend a colleague in another office (so serving another region of California) that we could survey? If so, please provide their email address.

The California IOUs are conducting another study for interior installations, and you may be contacted for a survey for that study.

{{{If they comment that they either would like to participate, or would not like to participate, note this and share with PG&E for the Navigant study of interior fixtures}}}

Thank you again for your help. If you have any questions on this survey, please feel free to contact me or my colleagues here at TRC Energy Services at {{{phone number}}}.

MANUFACTURER DRAFT SURVEY GUIDE

Italics text is for script language.

Blue text is for script directive for the surveyor.

Recruitment Contact and Screening

Cold Calling:

Hello Mr./Ms. {{{name}}},

My name is {{{name}}} and I'm calling from TRC Energy Services on behalf of *use the local utility of the person being surveyed*. We are surveying key professionals involved in the manufacture and sales of exterior luminaires in California. This research will provide critical information for the utilities and the California Public Utilities Commission to understand the market and assist utilities to develop energy efficiency rebate programs.

Our conversation will take at 30 minutes, and all individual responses are anonymous. As a thank you for participation, we can mail you a \$50 American Express gift card after completion of the survey. We would also be happy to send you a summary of study results once it is published.

S1: I'll primarily be asking about percentages of exterior luminaires that you manufactured and sold in the past 12 months broken down by light source technology. Are you knowledgeable of your company's sales of exterior luminaires?

[Response]

Yes →

When would you like to schedule a 20-30 minute time to talk?

Identify a time. If they would prefer to speak right then, move forward with survey. The preference is to schedule the survey for later, so they have time to think through some of the questions

Thanks, I'll send you a calendar invitation for *time and date*. It will include the topics we'll cover in the survey, to help you start thinking about responses. What email address should I use for the calendar invitation?

No →

Who is a better person at you company to talk to about exterior luminaire sales that includes California?

Get a name for the person if there is a referral and thank the respondent again. Document the contact in the tracking spreadsheet and move to next contact

Thank you for your willingness to participate in this important survey.

If they cannot accept a gift card, provide them with an option to donate the \$50 to a charity. Respondents can choose from St. Jude's Children's Hospital, United Way, or Doctors without Borders

Section A: Definitions

Surveyor Notes:

- Several of these product categories have a correlating category in the Design Lights Consortium (DLC) Qualified Products List (QPL). Some, like the Fuel Canopy and Parking Garage categories have specific light output limits in the QPL that make the definition very specific so that a typical product that may be mounted in a similar manner may not truly meet the category definition. We are using the DLC QPL definitions for this discussion.
- If they ask for clarification during the survey, here are definitions for new construction, retrofits, renovations, and replacements:
 - New Construction – Projects that create a new building or additions to an existing building that add square footage or similarly adding new hardscape to a property.
 - Retrofits and Renovations.
 - o Retrofits are projects that are primarily intended to replace or update existing exterior lighting systems with new lighting equipment.
 - o Renovations – Projects that involve renewal of the exterior lighting system, typically motivated by changes in use of the space, or by the need to update the space aesthetically}}
 - Replacements – replacing just lamps or luminaires that have failed or burned out

Section B: Luminaire sales Information

Q1. To start, please tell me your title, and briefly describe your role.

{{Record responses. This will also be used as a second screener question. If they do not appear to be involved in exterior luminaire sales, request the name of someone at their company that is and thank them for their time}}

Q1b: Can you provide sales information specifically for California? If not, for what region do you have information on sales for your company?

{{Record region. If the region is California, the Western U.S., or U.S., continue with survey. If not, ask for a referral and thank respondent again}}

For this survey, we are only interested in product sales in California {{or their region}} within the past 12 months. We will also discuss some future projections for California towards the end.

Q#2 What product categories of those we introduced does your company manufacture? Please answer yes, no, or only a little for each.

	Yes	No	A little
1. Street Lighting for lighting streets and roads.			
2. Pole-Mounted includes traditional parking lot pole-mounted, and decorative pedestrian products.			
3. Wall-Mounted includes wal-paks, sconces, and entry lights.			
4. Flood & Spot Lighting for aiming towards a subject or area.			
5. Bollards are primarily below 4 feet and are ground mounted and light paths and paved areas.			
6. Fuel Canopies are typically for gas station canopy applications. and I'm calling from TRC Energy Services on behalf of			

7. Parking Garage luminaires, such as linear and shoebox style fixtures.			
8. Pool Lighting for mounting underwater in pools or other water features.			
9. Street Sign Lighting to illuminate street names, and typically hangs from the signal pole arms.			

Section C: Purchased Fixtures

I'll be asking questions about percentages of your sales, and these refer to percentage by numbers of luminaires, not percentage by dollars.

{{{if they indicated they can estimate California sales, also read:}}} Please remember, this is for luminaires sold in the California market in the past 12 months.

Q#3 Please provide an approximate breakdown of the percentage of your exterior luminaire sales in California that go to:

1. **New construction** – meaning new buildings or additions, vs.
2. **Retrofits**– meaning replacements, renovations, or updates to all exterior luminaires in an area, vs.
3. **Replacements** – meaning replacements of just failed luminaires

{{{if they cannot distinguish between new construction and retrofit / renovation sales, fill out the last column}}}

Product Category	New Construction %	Retrofit and Renovation %	Replacements %	Combined Sales (If not sure of split between NC and Retro/Ren and replacements)
Street Lighting				
Pole-Mounted				
Wall-Mounted				
Flood & Spot				
Bollard				
Fuel Canopy				
Parking Garage				
Pool lighting				
Street Sign Lighting				

{{{if they indicated in Q3 that they cannot distinguish between new construction and retrofit sales, remove "For New Construction luminaire sales" in Q4}}}

For the remainder of this survey, please provide responses in the context of your installations for new construction and retrofits. Toward the end, I'll ask a few questions about replacement, but for now, don't include replacements in your responses.

Q#4 For all New Construction exterior luminaire sales, what is the overall breakdown of your sales percentages by technology? Let's start with LEDs.

{{{Start with LED. As you go down the list, they may re-think the LED number, so be flexible to adjust that as they make corrections. If they don't and you start to overshoot 100% by over 20%, ask them to re-evaluate the largest ones based on the context of the answers they made for the smaller shares}}}

	Percentage
LED	
Metal Halide	
HPS	
LPS	
Linear FL	
CFL	
Other	

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit sales, remove "for New Construction" in Q5}}}

Q#5 You stated LEDs are approximately {{{insert the value reported in the table in Q4 for LEDs}}} of the total sales of exterior luminaires for New Construction. Would you estimate it's higher, lower, or the same for each product category? If different, please provide an approximate percentage for LED sales for that category.

Product Category	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit sales, skip to Q8}}}

We'll now ask the same question for Retrofit and Renovations. Remember, we're talking about sales in the past 12 months. {{{If they indicated they can estimate California sales, also read:}}} in the California market.

Q#6 For all Retrofit and Renovation luminaires, what is the overall breakdown of your total exterior lighting sales percentages by technology? Let's start with LEDs.

	Percentage
LED	
Metal Halide	
HPS	
LPS	
Linear FL	
CFL	
Other	

Q#7 You stated that LEDs represent approximately *{{{insert the value reported in the table in Q#6 for LEDs}}}* of the total sales of exterior luminaires for Retrofit and Renovations. Would you estimate that the LED percentage is higher, lower, or the same for each product category?

Product Category	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
Bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Section D: Efficacy

We'll now ask some questions on luminaire efficacy. *{{{If they indicated they can estimate California sales, also read}}}* Recall that we're only discussing sales in California.

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit / renovation sales, remove "For New Construction projects" in Q8}}}

Q#8 Focusing on LED luminaires, let's discuss breakdowns by DesignLights Consortium (DLC) ratings for the LED products you sell. For New Construction projects, what percentages of your exterior LED luminaires sold are DLC Listed?

	Percent
DLC Premium	
DLC Standard	
not DLC listed	

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit / renovation sales, skip to Q10}}}

Q#9 For Retrofit and Renovation work, what percentage of your exterior LEDs sold are DLC Listed?

	Percent
DLC Premium	
DLC Standard	
not DLC listed	

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit / renovation sales, removed "for Retrofit and Renovation" in Q10}}}

Q#10 Does this vary by product category? If so, for Retrofit and Renovation, how does DLC Premium and Standard listing percentages differ (higher or lower) for these product categories?

Product Category	DLC premium (%)	DLC standard (%)	Not DLC listed (%)
street lighting			
pole-mounted			
wall-mounted			
flood & spot lighting			
bollard			
fuel canopy			
parking garage			
pool lighting			
street sign lighting			

Q#11 Do you sell LED exterior lighting products that DO NOT have the DLC QPL listing but meet the efficacy requirements of the QPL? If so, what percentage of the total exterior luminaires that you sell are not QPL listed but would likely meet the Premium or Standard listing levels?

{{{This table should total no more than the value in Q#10 for the "Not DLC Listed" result, but it doesn't need to equal that value. Some products could be not listed AND not able to meet the efficacy requirements}}}

	Percent
would meet DLC premium	
would meet DLC standard	

Q#12 For products that meet the efficacy requirements of the QPL, what are reasons that your company chooses not to have them DLC listed?

Q12b. Now I'm going to ask about efficacy more directly. For each product category, can you please give me an estimate of your LED sales by efficacy bin? The bins are <90 Lumens per watt (Lm/W), 90-100 Lm/W, 100-110 Lm/W, 110-120 Lm/W, and >120 Lm/W.

	<90	90-100	100-110	110-120	>120
street lighting					
pole-mounted					
wall-mounted					
flood & spot lighting					
Bollard					
fuel canopy					
parking garage					
pool lighting					
street sign lighting					

Section E: Future Projections

{{{If they indicated in Q3 that they cannot distinguish between new construction and retrofit sales, remove "for New Construction" in Q12 and Q13, and skip Q14 and Q15}}}

Q#13 So far, we've discussed recent sales. Let's talk briefly about projections. You indicated that LEDs comprised approximately *{{{use the LED value from Q#4 above}}}* of your exterior luminaire sales for New Construction for the past 12 months. In the next 2 years, do you expect the percentage of LEDs to increase, decrease, or stay about the same? If different, please provide an approximate percentage.

{{{Record higher, lower, or the same; if higher or lower, record percentage}}}

Q#14 Approximately what percentage of your exterior luminaire sales do you expect to be LEDs in 5 years, for New Construction?

{{{Record higher, lower, or the same; if higher or lower, record percentage}}}

Q#15 Similarly for Retrofits and Renovations: You indicated that LEDs comprised approximately *{{{use value from Q#6 above}}}* of your exterior luminaire sales for Retrofits and Renovations for the past 12 months. In the next 2 years, do you expect the percentage of LEDs to increase, decrease, or stay about the same? If different, please provide an approximate percentage.

{{{Record higher, lower, or the same; if higher or lower, record percentage}}}

Q#16 Approximately what percentage of your exterior luminaire sales do you expect to be LEDs in 5 years, for Retrofits and Renovations?

{{{Record higher, lower, or the same; if higher or lower, record percentage}}}

Q#17 Thinking back to the product categories we discussed, do you anticipate that any product category will be lower or higher than the *{{{use value from Q#16 above}}}* percent you estimated for Retrofits and Renovations in 5 years? *{{{Only ask for product categories that they reported they sell}}}*

Product Category	lower or higher?	new %
street lighting		
pole-mounted		
wall-mounted		
flood & spot lighting		
Bollard		
fuel canopy		
parking garage		
pool lighting		
street sign lighting		

Section F: Existing fixtures that are replaced

We are almost near the end of the survey. I'd like to ask about existing fixtures that have been replaced or retrofitted in the past 12 months. *[[[If they indicated they can estimate sales for California only, also read:]]]* Remember that we're only discussing California.

Q#18 Can you provide a breakdown of the light source technologies (by percentage) that you see being replaced in exterior lighting systems with the new lighting products you sell?

[[[The total across per row should be approximately 100%. Focus on getting the top two or so values. If total values exceed 120%, ask them to reconsider earlier responses. They may not know the answer to this question]]]

	LED	Metal Halide	HPS	LPS	Linear Fluorescent	CFL	Other
street lighting							
pole-mounted							
wall-mounted							
flood & spot lighting							
Bollard							
fuel canopy							
parking garage							
pool lighting							
street sign lighting							

Section G: Finish

Q#19 Finally, can you please estimate the total number of exterior luminaires your company has manufactured in the past 12 months *[[[if they indicated they can estimate California sales, add]]]* in California? The purpose of this question is so we can weight responses from our various respondents based on market share. Would you say it's:

- a. <10,000
- b. Between 10,000 and 100,000
- c. Between 100,000 and 1,000,000
- d. Between 1,000,000 and 10,000,000
- e. >10,000,000

[[[If they decline answering this question, that's fine]]]

Thank you so much for participating in this survey.

Q#20 We'd like to send you a \$50 gift card. Can you provide a mailing address to send this to? We won't use the address for any other purpose except the gift card, which will take about 6 weeks to arrive.

Q#21. Would you like us to send you an email with the report link when it is completed?

[[[If yes, ask for email address if you don't have it already]]]

MEMORANDUM (continued)

To: Reggie Wilkins (SCE) and IOU collaborators

July 12, 2018

Re: Revised Survey Guide for the Exterior Lighting Baseline Standard Practice and Workpaper Support Study

{{{If they indicated in Q#2 they sell pool lighting or street signage lighting:}}} Q#22 Since you manufacture {{{pool lighting and/or street signage lighting}}}, can you please recommend 2 to 3 dealers that sell those products in California?

The California IOUs are conducting another study for interior sales. TRC isn't the consultant, but you may be contacted for a survey for that study.

{{{If they comment that they either would like to participate, or would not like to participate, note this and share with PG&E for the Navigant study of interior fixtures}}}

Thank you again for your help. If you have any questions on this survey, please feel free to contact me.