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October 15, 2019

MEMORANDUM

To: Reginald Wilkins (SCE), IOU EM&V and Lighting Engineering Staff, and CPUC Lighting staff

From: David Douglass-Jaimes, Marian Goebes, Pranav Goray, Neil Perry, Mia Nakajima (TRC)

Re: Statewide Interior Lighting Standard Practices Study: Final Analysis (CALMAC Study ID SCE0437.01)

FINAL ANALYSIS

Executive Summary

In response to California Public Utilities Commission (CPUC) dispositions, the Investor Owned Utilities (IOUs) - led by Southern California Edison (SCE), requested that TRC conduct a study to investigate standard practice baselines of interior lighting. The purpose of the project is to support work paper updates for interior lighting products for the following product categories: linear ambient, downlights, and high bay / low bay applications.

Research questions for the study were as follows:

- What fraction of commercial interior linear retrofit sales are LED fixtures vs. LED retrofit kits vs. tubular LED (TLED) or other LED lamps? To the degree possible, how does this vary by product category (troffers, high bay / low bay)? To the degree possible, what are customers decision-making processes for selecting which option to install? And, how if at all, do permitting requirements affect this decision?
- What is the current standard practice efficacy for fixtures, retrofit kits, and TLEDs or lamps? To the degree possible, how does this vary between product category (troffers, downlights, high bay/ low bay), and what is the range of efficacies within product categories? What is the projected standard practice for the next five years?

TRC addressed the research questions outlined above through three primary data collection efforts:

- Navigant distributor sales data analysis
- Literature review and comparison of efficacy results to DesignLights Consortium (DLC) standards and database listings
- Program and implementer staff interviews

Note that this study uses the term “fixtures” interchangeably with “luminaires”. “Luminaires” is the technically correct term, so is used here when presenting data. “Fixtures” is often used in the market, was used by the IOUs when scoping this study, is used in CPUC dispositions, and was used in a research studies referenced here. TRC preserved the use of “fixtures” when discussing the research questions, CPUC dispositions, and past studies that use this term.

Figure 1, below, shows unit sales and proportions for luminaires, retrofit kits, and TLEDs for all linear LED product types, including high-bay and low-bay applications, and TLED replacement lamps. While LED luminaires and retrofit kits typically replace incumbent technologies on a one-for-one basis, two or more TLED lamps are often required to fully retrofit a single linear fluorescent luminaire. To address this discrepancy, TRC also estimated the proportion of luminaires affected for each application type, determined based on the average lamps per luminaire type as documented in the California Commercial Saturation Study (CSS) (Itron Inc., 2014). Based on the CSS, TRC assumed that linear fluorescent luminaires have an average of 2.5 lamps per luminaire for these calculations.

As Figure 1 shows, luminaires makes up a slight majority (52%) of linear product unit sales, with TLED lamps making up 42% and retrofits kits representing 6% of unit sales. When considering the proportion of luminaires affected, TRC estimated luminaire products to represent 69% of the market, while TLED lamps and retrofit kits represent 22% and 9% respectively.

Figure 1. Linear LED Product Sales
(*To estimate effected luminaires, TRC assumes luminaire and retrofit kit sales are one-for-one replacements, and TLED lamps are installed at an average rate of 2.5 lamps per luminaire)

Linear LED Products	Unit Sales	Proportion of Unit Sales	Estimated Proportion of Affected Luminaires*
Linear Luminaires	2,664,700	52%	69%
Linear Retrofit Kits	331,700	6%	9%
TLED Lamps	2,130,900	42%	22%
Total Units	**5,127,300**		

Overall, the sales analysis indicates that:

- Among linear products, after normalizing by the number of lamps per luminaire, luminaires comprise the most sales (69%), followed by TLEDs (22%), followed by retrofit kits (9%).
- Among TLEDs, UL Type A TLEDs dominate sales (94%).
- Among downlight products, after normalizing by the number of lamps per luminaire, luminaires comprise just over half of sales (53%), followed by pin-based LED lamps for CFL replacements (29%), followed by downlight retrofit kits (18%).
- Compared to the BPA Non-Residential Lighting Market Characterization (BPA, 2017), sales trends in California show greater proportions of linear luminaire and TLED sales compared to retrofit kits, and smaller proportion of downlight luminaires compared to lamps and retrofit kits. This may be due to differences in policy and program priorities between BPA and California, as well as differences in time periods covered in the different data sets. More details on the BPA study findings are in the Appendix.

In addition to unit sales data, Navigant also provided sales weighted efficacies for each product type, as well as percent of sales by efficacy bin for each product type (exact efficacies were not available). Efficacy bins in the distributor data range from 50-60 lumens per Watt to greater than 150 lumens per Watt (>150 lm/W). Based on the

sales weighted efficacies for each product type, TRC calculated sales weighted efficacies for each application type of interest to the study: linear ambient, high-bay/low-bay, downlights, and lamp replacements. Figure 2, below, summarizes the efficacy values based on the sales volumes as well as efficacy bin ranges for each application type.

Figure 2. Summary of Sales Weighted Efficacies and Efficacy Bin Ranges by Product Type

Product Type	Unit Sales	Sales-Weighted Average Efficacy	Efficacy Bin Range
Linear Ambient Luminaires/Retrofit Kits	2,511,000	110	50 – >150
High-Bay/Low-Bay Luminaires/Retrofit Kits	485,400	136	100 – >150
Downlight Luminaires/Retrofit Kits	2,561,000	65	50 – 110
T8/T5/T5HO Replacement Lamps	2,130,900	129	100 – >150
Pin-Base LED Lamps for CFL replacement	1,392,000	91	60 – 140

In addition to compiling current product efficacies, TRC estimated efficacies projected to 2024 for each application type, based on the current values in the distributor data. TRC calculated efficacy projections based on percent increases in efficacy as estimated by the US Department of Energy in its “Energy Savings Forecast of Solid-State Lighting in General Illumination Applications” (DOE, 2016).

Figure 3 shows efficacy projections through 2024, based on the distributor sales weighted efficacies data.

Figure 3. Application Type Efficacy Projections based on Distributor Sales Weighted Efficacies

Application Type	Sales-Weighted Average Efficacy 2017	2018 Efficacy	2019 Efficacy	2020 Efficacy	2021 Efficacy	2022 Efficacy	2023 Efficacy	2024 Efficacy
Linear Ambient Luminaires / Retrofit Kits	110	114	117	121	124	128	131	135
High-Bay/Low-Bay Luminaires / Retrofit Kits	136	140	144	148	152	156	160	164
Downlight Luminaires / Retrofit Kits	65	68	70	73	75	78	81	83
T8/T5/T5HO Replacement Lamps	129	133	137	141	145	149	152	156
Pin-Base LED Lamps for CFL replacement	91	94	96	99	101	104	106	109

TRC also compared our efficacy results with the California Public Utilities Commission (CPUC) (Draft Resolution E-5009, 2019), and with products in the DLC database.

This analysis of sales weighted average efficacies and efficacy projections indicates that:

- Draft Resolution E-5009 efficacy values for linear LED products are at the low end of the range of efficacy values found in the distributor data set. If the CPUC intends to maintain the practice of setting a baseline that most available technologies would exceed, the efficacy values the agency has identified for these product categories align with that methodology. Note that the distributor data set includes products incentivized by programs – which likely inflates average efficacy values, because it was not possible to separate those products out.
- Draft Resolution E-5009 efficacy values are roughly consistent with DLC Standard *minimum* efficacy values for equivalent product types.
- Sales weighted average efficacy values from the 2017 distributor sales data set appear to be relatively consistent with the *average* efficacy values of products listed in the DLC-listed product database.

Introduction

In response to CPUC dispositions, the electric Investor Owned Utilities (IOUs) - led by Southern California Edison (SCE), requested that TRC conduct a study to investigate standard practice baselines of interior lighting. The purpose of the project is to support work paper updates for interior lighting products for the following product

categories: linear ambient, downlights, and high bay / low bay applications. This memo is the final deliverable and provides our methodology and results.

Figure 4 shows research questions for the study.

Figure 4. Research Questions

Research question	Purpose	Task for Investigation
What fraction of commercial interior linear retrofit sales are LED fixtures vs. LED retrofit kits vs. tubular LED (TLED) or other LED lamps? To the degree possible, how does this vary by product category (troffers, high bay/ low bay)? To the degree possible, what are customers decision-making processes for selecting which option to install? And, how if at all, do permitting requirements affect this decision?	The results will be used as workpaper inputs in 2021 and beyond for incremental measure cost (IMC) calculations. The fraction of sales that are TLEDs will have a significant impact on the IMC, since TLEDs are considerably less expensive than LED fixtures.	Estimate Fraction of Sales that are LED Linear Fixtures vs. LED Linear Retrofit Kits vs. TLED Lamps
What is the current standard practice efficacy for fixtures, retrofit kits, and TLEDs or lamps? To the degree possible, how does this vary between product category (troffers, downlights, high bay/ low bay), and what is the range of efficacies within product categories? What is the projected standard practice for the next five years?	The results will be used as workpaper inputs in 2021 and beyond for standard practice efficacy assumptions.	Estimate Current and Future Standard Practice Efficacy

TRC addressed the research questions through three primary data collection efforts. TRC lists these efforts in order of most to least significant in impacting results.

- **Navigant distributor data:** Navigant collected data from distributors and online as part of the "California Statewide Non-Residential LED Quality and Market Characterization Study" (Navigant, 2018). Navigant's distributor sales data came from three large distributors, representing 20% of the California lighting distributor market. TRC obtained distributor sales data from Navigant to estimate the fraction of TLEDs, linear retrofit kits, and linear LED fixtures in the distributor data set. Within the fraction of TLEDs, Navigant was able to differentiate amongst Underwriters Laboratories (UL) Type A, B, or C. This sales data also included sales-weighted efficacies for each product type, which was used to inform standard practice and projected efficacies.
- **Literature Review and DesignLights Consortium (DLC) comparison:**
  - To inform the fraction of sales that are luminaires, retrofit kits, and lamps, TRC reviewed a study from Bonneville Power Administration (BPA, 2017), which estimates quantity and relative percent of LED sales by product type, and a DesignLights Consortium (DLC, 2018) report.
  - To inform current efficacy, TRC compared efficacy values found in the distributor data set with DLC minimum requirements and with products available in the DLC database.

- To inform efficacy projections, TRC reviewed literature to identify estimates of percent improvements in efficacy over time, including U.S. Department of Energy (DOE) reports.

- **Program and implementer staff interviews:** TRC conducted interviews with five commercial lighting program implementers and California IOU staff that manage commercial lighting programs to provide additional information into the market share of these retrofit options. Due to the small sample size, these interviews are intended to provide context for study findings, but do not provide quantitative data. Interviewees provided feedback on the sales data findings and customers' decision-making processes for selecting which option to install (TLEDs, retrofit kits, or fixtures).

Distributor Sales Data

The tables in the following sections outline the distributor sales data analysis results showing the proportions of sales for various LED product types. The data shown here is based on the Navigant distributor data, which reflected 2017 sales data. Navigant received sales data from three distributors, which they estimated represented approximately 20% of the California lighting distributor market. Navigant provided TRC with unit sales and sales weighted efficacies for each of the LED product types outlined below in Figure 5. These product type categories align with product type definitions (DLC). The distributor data set includes products incentivized by programs, because it was not possible to distinguish program-incentivized sales from non-incentivized sales.[1]

[1] Distributor data did not track program-incentivized from non-program incentivized sales.

Figure 5. Product Types Included in Study

Linear Ambient	High-Bay/Low-Bay	TLED - T8/T5/T5HO Replacement Lamps	Downlight
♦ 1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces ♦ Direct Linear Ambient Luminaires ♦ Integrated-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces ♦ Linear Ambient Luminaires with Indirect Component ♦ Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces ♦ Retrofit Kits for Direct Linear Ambient Luminaires	♦ High-Bay Luminaires for Commercial and Industrial Buildings ♦ Low-Bay Luminaires for Commercial and Industrial Buildings ♦ Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	♦ Type A (works with linear fluorescent ballast) ♦ Type B (ballast bypass) ♦ Type C (remote LED driver)	♦ Downlight Luminaires ♦ Downlight Retrofit Kits ♦ Pin-Base LED Lamps for CFL replacement

Split of TLED, Luminaire and Retrofit Kit Sales (2017)

Figure 6 shows unit sales and proportions for luminaires, retrofit kits, and TLEDs for all linear LED product types, including high-bay and low-bay applications, and TLED replacement lamps. Note that all product sales data presented in this section represents the entire lighting market, including both new construction and retrofit applications. While LED luminaires and retrofit kits typically replace incumbent technologies on a one-for-one basis, two or more TLED lamps are often required to fully retrofit a single linear fluorescent luminaire. To address this discrepancy, TRC also estimated the proportion of luminaires affected for each application type, determined based on the average lamps per luminaire type as documented in the California CSS (Itron Inc., 2014). Based on the CSS, TRC assumed that linear fluorescent luminaires have an average of 2.5 lamps per luminaire for these calculations. The Appendix provides supporting documentation for this estimate.

As Figure 6 shows, luminaires comprise a slight majority (52%) of linear product unit sales, with TLED lamps making up 42% and retrofits kits representing 6% of unit sales. However, when considering the proportion of luminaires

affected, TRC estimates that luminaire products to represent 69% of the market, while TLED lamps and retrofit kits represent only 22% and 9% respectively.

Figure 6. Linear LED Product Sales, 2017
(*To estimate affected luminaires, TRC assumes luminaire and retrofit kit sales are one-for-one replacements, and TLED lamps are installed at an average rate of 2.5 lamps per luminaire)

Linear LED Products	Unit Sales	Proportion of Unit Sales	Estimated Proportion of Luminaires Affected*
Linear Luminaires	2,664,700	52%	69%
Linear Retrofit Kits	331,700	6%	9%
TLED Lamps	2,130,900	42%	22%
Total Units	**5,127,300**		

The Bonneville Power Administration included sales trends for the Pacific Northwest as part of its Non-Residential Lighting Market Characterization (BPA, 2017). Results, shown in Figure 32 in the Appendix, show that among linear fixtures (which would include retrofit kits) and TLEDs, TLEDs comprise slightly more than half of unit sales (approximately 55%, based on visual inspection of a BPA figure), while fixtures and retrofit kits comprise the remainder. Based on our analysis of the distributor sales data for California for linear products, TLEDs comprise slightly less than half of unit sales (42%), compared with linear retrofit kits and fixtures. Thus, the studies found results within the same ballpark range, although the BPA results found a higher fraction of TLEDs. The larger fraction of TLEDs found in the BPA study may be because of differences in policy and program priorities between BPA and California, as well as differences in time periods covered in the different data sets.

Figure 6 aggregates all types of linear products. TRC also considered sales proportions for specific product types and applications, as shown in the figures that follow.

Figure 7 shows unit sales and proportions for different types of TLED products. As shown, by far the greatest share of TLED sales is Underwriters Laboratories (UL) Type A, the only type compatible with existing linear fluorescent (LFL) ballasts and therefore not requiring any additional modifications to existing luminaires.

Figure 7. TLED Product Sales, 2017

TLED Products	Unit Sales	Proportion of Unit Sales
UL Type A – works with LFL ballast	2,008,700	94%
UL Type B – ballast bypass	75,700	4%
UL Type C – remote LED driver	46,600	2%
Total Units	**2,130,900**	

Figure 8 shows unit sales for linear ambient LED luminaire and retrofit kit products. As shown, troffer type luminaires (2x4, 2x2, etc.) and direct linear ambient luminaires are the largest categories, with retrofit kit types selling in small proportions, and linear ambient luminaires with indirect component comprising less than one percent of sales. In total, luminaire products make up roughly 87% of linear ambient sales, with retrofit kit products making up 13%.

Figure 8. Linear Ambient Product Sales, 2017

Linear Ambient Products	Unit Sales	Proportion of Unit Sales
1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	1,299,500	52%
Direct Linear Ambient Luminaires	885,900	35%
Linear Ambient Luminaires with Indirect Component	1,200	<1%
Integrated-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	110,100	4%
Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	138,200	6%
Retrofit Kits for Direct Linear Ambient Luminaires	76,100	3%
Total Units	**2,511,000**	

Figure 9 shows unit sales and proportions for high-bay and low-bay LED products. High-bay luminaires comprise the largest category by far, with low-bay luminaires and retrofit kits for low-bay luminaires making up only 4% and 2%, respectively. The distributor sales data from Navigant did not include any retrofit kits for high-bay luminaires.

Figure 9. High Bay/Low Bay Product Sales, 2017

High-Bay/Low-Bay Products	Unit Sales	Proportion of Unit Sales
High-Bay Luminaires	457,000	94%
Low-Bay Luminaires	21,100	4%
Retrofit Kits for Low-Bay Luminaires	7,300	2%
Total Units	**485,400**	

In addition to the linear product analysis described above, TRC also looked at sales data for downlight products and lamp replacement products for CFL downlights. Figure 10 shows sales proportions for downlight LED products and pin-based LED lamps for CFL replacement. As with the linear products described above, since this includes both luminaire and lamp products, TRC also estimated the proportion of luminaires affected for each application type,

determined based on average lamps per luminaire type as documented in the CSS. For these calculations, TRC assumed that downlight luminaires have an average of 1.3 lamps per luminaire. The Appendix provides supporting documentation for this estimate.

As Figure 10 shows, downlight luminaires have the highest proportion of unit sales at 49%, followed by pin-based LED lamps at 35%, and downlight retrofit kits at 16%. From the perspective of affected luminaires, luminaire products represent 53% of the market, with pin-based LED lamps making up 29%, and retrofit kits at 18%. By both metrics, the downlight category has the highest penetration of retrofit kit products, compared to linear ambient and high-bay/low-bay applications.

Figure 10. Downlight LED Product Sales, 2017
(*To estimate affected luminaires, TRC assumes luminaire and retrofit kit sales are one-for-one replacements, and pin-based lamps are installed at an average rate of 1.3 lamps per luminaire)

Downlight LED Products	Unit Sales	Proportion of Unit Sales	Estimated Proportion of Affected Luminaires*
Downlight Luminaires	1,924,400	49%	53%
Downlight Retrofit Kits	636,600	16%	18%
Pin-Base LED Lamps for CFL replacement	1,392,000	35%	29%
Total Units	**3,953,000**		

Conclusions

This sales analysis indicates that:

- Among linear products, on a per-unit basis, the sales split is 52% luminaires, 42% TLEDs, and 6% retrofit kits. Compared to the Non-Residential Lighting Market Characterization (BPA, 2017), sales trends in California show a smaller proportion of TLEDs compared with linear luminaires and retrofit kits. After normalizing by the number of lamps per luminaire, luminaires comprise the most sales (69%), followed by TLEDs (22%), followed by retrofit kits (9%).
- Among TLEDs, UL Type A TLEDs dominate sales (94%).
- Among downlight products, on a per-unit basis, the sales split is 49% luminaires, 35% pin-based LED lamps, and 16% retrofit kits. After normalizing by the number of lamps per luminaire, luminaires comprise just over half of sales (53%), followed by pin-based LED lamps for CFL replacements (29%), followed by downlight retrofit kits (18%).

Sales Weighted Efficacy (2017)

Efficacy Based on Distributor Sales Data

In addition to unit sales data, Navigant provided sales weighted efficacies for each product type based on the distributor sales data, as well as percent of sales by efficacy bin for each product type (exact efficacies were not available). Efficacy bins in the distributor data range from 50-60 lumens per Watt to greater than 150 lumens per Watt (>150 lm/W). Figure 11, below, shows both the sales-weighted average efficacy for each product type, and the range of efficacy bins for each product type. Based on the sales weighted efficacies for each product type, TRC then calculated sales weighted efficacies for each application type of interest to the study: linear ambient, high-bay/low-bay, and downlights. Efficacy values for LED replacement lamp types are shown independently from the integrated luminaire products and are not included in the application type efficacies. Figure 11 summarizes the average efficacy values based on the sales volumes. Bold values indicate sales-weighted average efficacies by application type.

Figure 11. Sales Weighted Efficacies and Efficacy Ranges by Product Type and Application, 2017

Product Type	Unit Sales	Sales-Weighted Average Efficacy	Efficacy Bin Range
1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	*1,299,500*	*115*	*70 – >150*
Direct Linear Ambient Luminaires	*885,900*	*101*	*50 – >150*
Linear Ambient Luminaires with Indirect Component	*1,200*	*94*	*90 – 100*
Integrated-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	*110,100*	*106*	*80 – 150*
Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	*138,200*	*116*	*100 – 140*
Retrofit Kits for Direct Linear Ambient Luminaires	*76,100*	*123*	*90 – 140*
Total of Linear Ambient Luminaires/Retrofit Kits	**2,511,000**	**110**	**50 – >150**
High-Bay Luminaires	*457,000*	*136*	*100 – >150*
Low-Bay Luminaires	*21,100*	*134*	*100 – 150*
Retrofit Kits for Low-Bay Luminaires	*7,300*	*127*	*110 – 140*
Total of High-Bay/Low-Bay Luminaires/Retrofit Kits	**485,400**	**136**	**100 – >150**
Downlight Luminaires	*1,924,400*	*64*	*50 – 110*
Downlight Retrofit Kits	*636,600*	*68*	*50 – 90*
Total of Downlight Luminaires/Retrofit Kits	**2,561,000**	**65**	**50 – 110**

Product Type	Unit Sales	Sales-Weighted Average Efficacy	Efficacy Bin Range
Type A TLED	*2,008,700*	*129*	*110 – >150*
Type B TLED	*75,700*	*124*	*110 – 130*
Type C TLED	*46,600*	*137*	*100 – 150*
Total of T8/T5/T5HO Replacement Lamps	**2,130,900**	**129**	**100 – >150**
Pin-Base LED Lamps for CFL replacement	**1,392,000**	**91**	**60 – 140**
Total LED Unit Sales	**9,080,200**		

The efficacy values presented here represent the entire lighting market, including both new construction and retrofit applications. In addition, efficacy is just one of a number of metrics that determine the quality of a lighting product. Qualities that are desirable in certain commercial applications, such as lower color temperature (CCT) or higher color rendering (CRI), can often result in lower efficacies, whereas certain industrial or warehouse applications prioritize maximized efficacy over visual qualities. This data set is not differentiated by any visual quality factors, or any other performance metrics. Efficacy values shown above may also be affected by the relative amount of unit sales for each product type, where efficacies for product types with relatively low unit sales may be skewed either higher or lower by product sales that may not be representative of the broader market.

The following figures show the distribution of distributor sales by efficacy bin and product type, further illustrating the range of efficacies and the most common efficacy bins for most product types.

Figure 12 provides the distribution of the distributor sales data by efficacy bin for linear ambient luminaires and retrofit kits.

Figure 12. Linear Ambient Efficacy Distribution

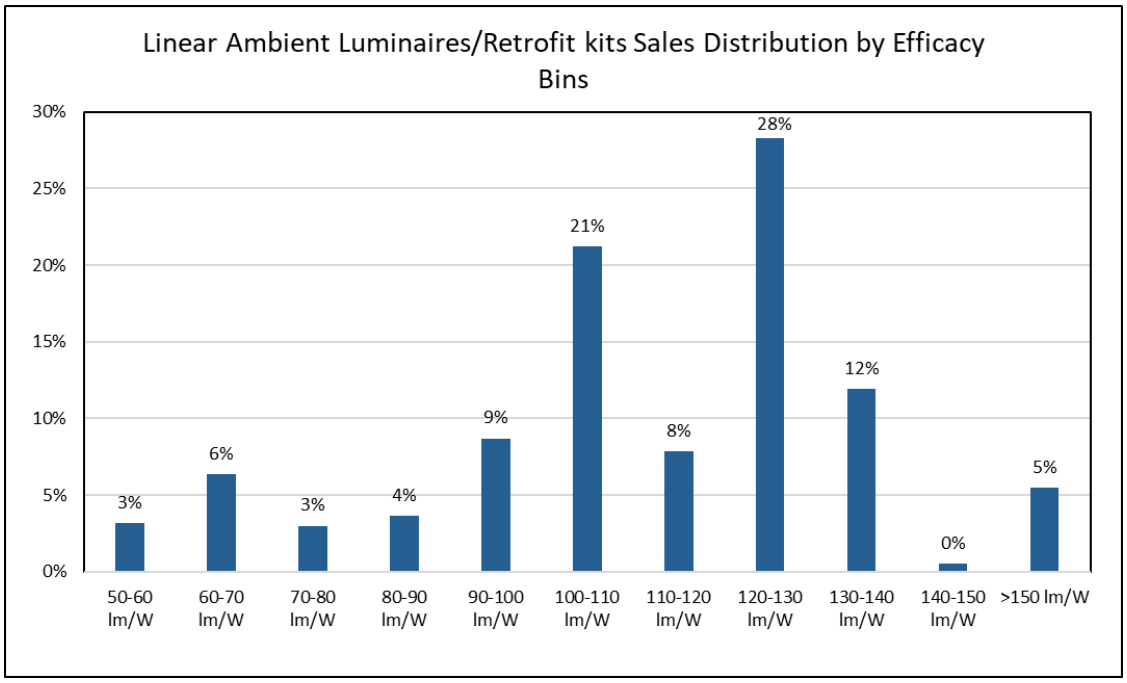


Figure 13 presents the same data, but shows cumulative percentiles by efficacy bin. For example, 3% of linear ambient luminaires and retrofit kits have an efficacy of 60 lm/W or lower, 10% have an efficacy of 70 lm/W or lower, 13% have an efficacy of 80 lm/W or lower, and so forth. The figure also shows the average efficacy. Note that the average (mean) is different from the 50% percentile (median). For this data set, the average (110 lm/W) corresponds to the 46%-percentile, while the median is somewhere in the 110-120 lm/W range. Given the large volume of data collected, Navigant provided data by efficacy bin (in increments of 10 lm/W), so TRC could not calculate the exact median value. Given the large volume of data collected, Navigant provided data by efficacy bin (in increments of 10 lm/W), so TRC could not calculate the exact median value.

Figure 13. Linear Ambient Efficacy Distribution – Cumulative Percentile

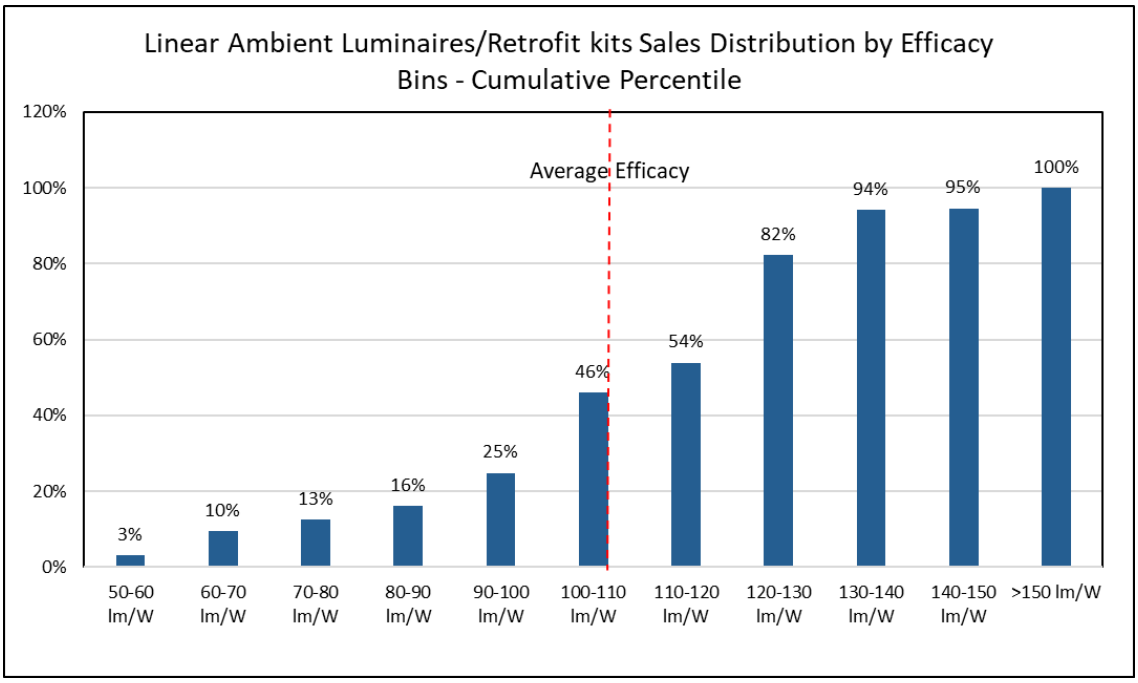
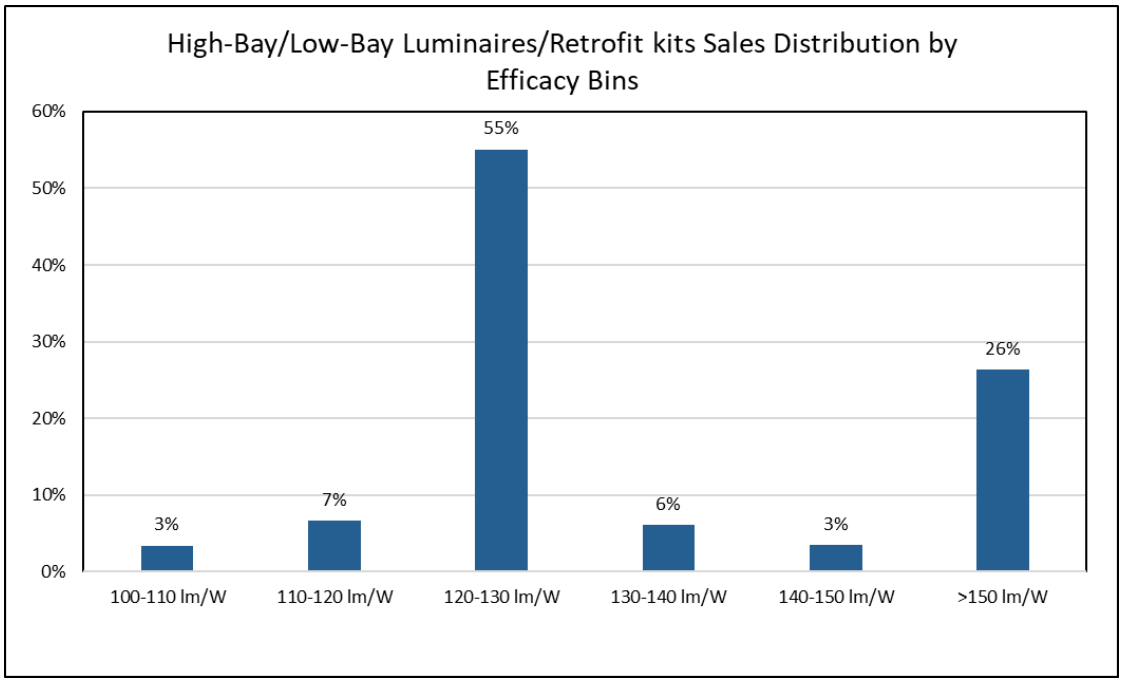


Figure 14 and Figure 15 provide similar information for high bay / low bay luminaires and retrofit kits. These products have less variation than linear luminaires and retrofit kits. Interestingly, there is a significant gap between the two efficacy bins with the largest sales for high bay / low bay luminaires and retrofit kits: the 120-130 lm/W and > 150 lm/W. As illustrated, the majority of products are in the 120-130 lm/W range, but the average efficacy is skewed upwards because of the products with efficacy above 150 lm/W.

Figure 14. High Bay / Low Bay Efficacy Distribution



For high bay / low bay luminaires, the average (136 lm/W) is higher than the median (50th percentile), which is somewhere in the 120-130 lm/W range.

Figure 15. High Bay / Low Bay Efficacy Distribution – Cumulative Percentile

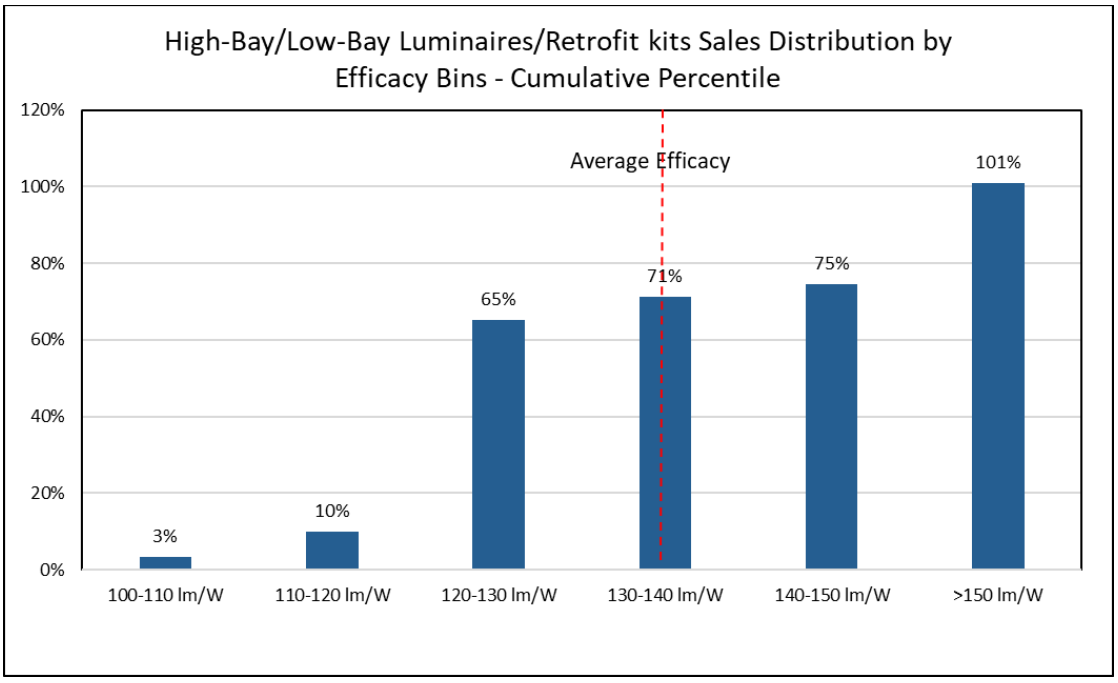


Figure 16 and Figure 17 show similar results for downlights. As shown, the majority of products have an efficacy at or below 70 lm/W.

Figure 16. Downlight Efficacy Distribution

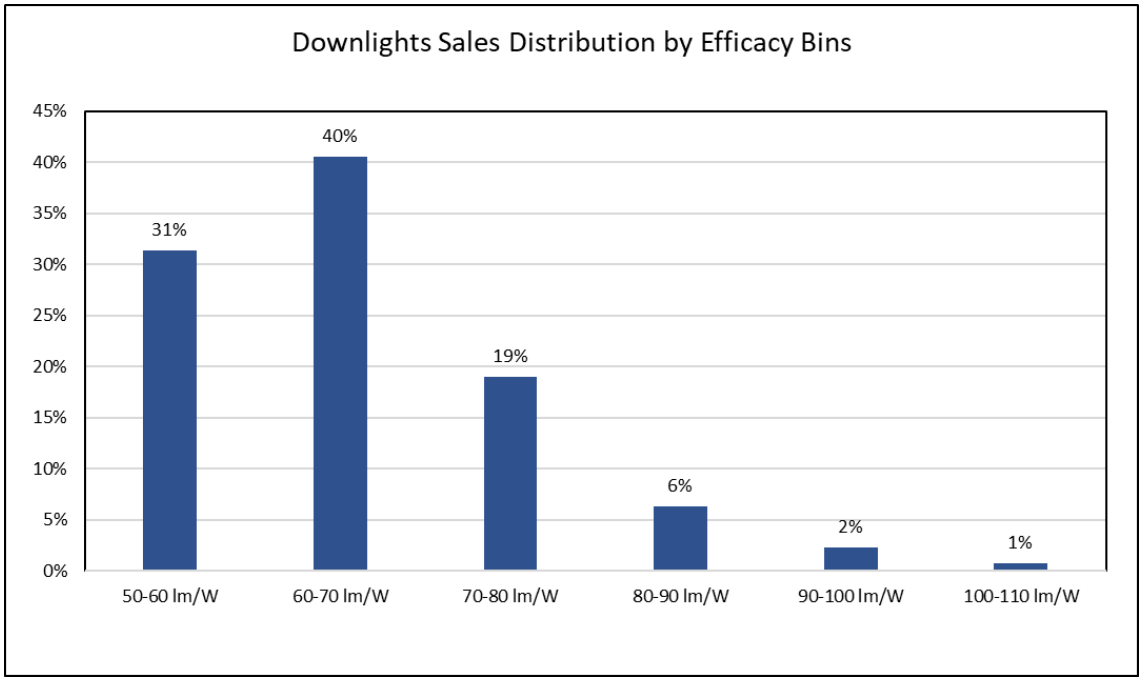
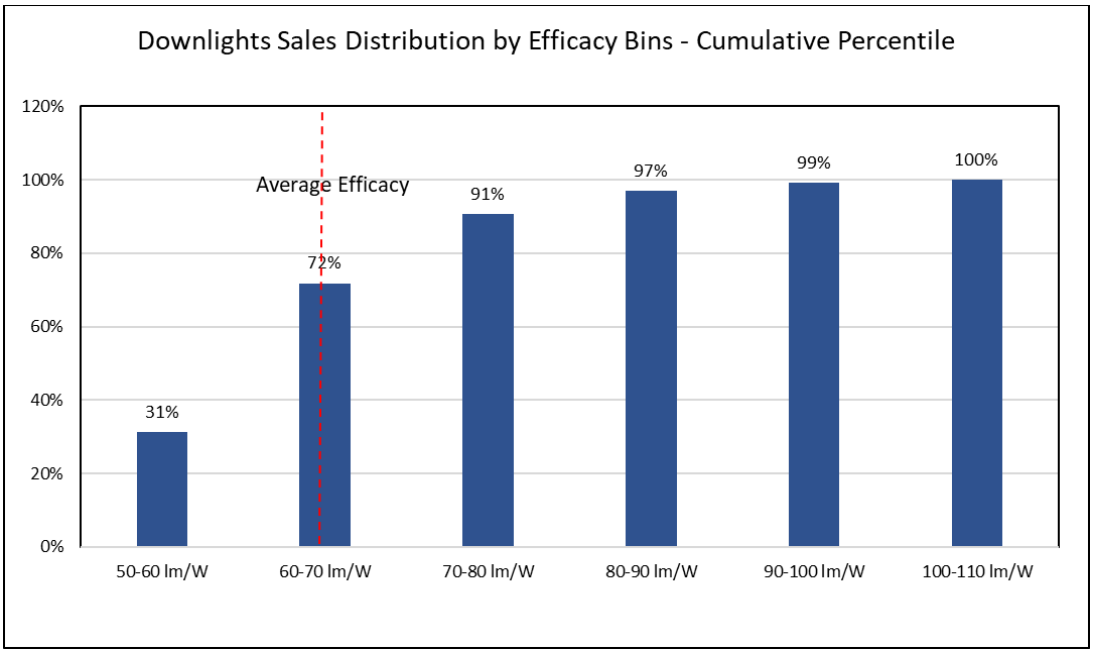


Figure 17. Downlight Efficacy Distribution – Cumulative Percentile



The next two figures show results for pin-based LED replacement lamps for CFL. As shown, most products have an efficacy at or below 100 lm/W, and a third of products have an efficacy at or below 80 lm/W.

Figure 18. Pin-Based Efficacy Distribution

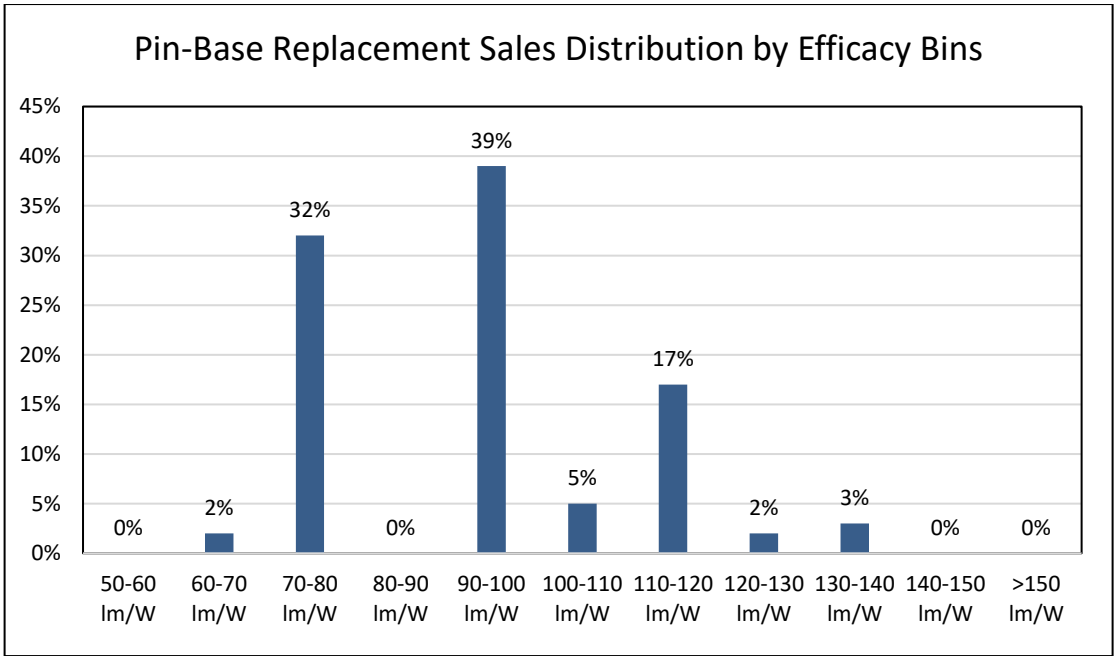
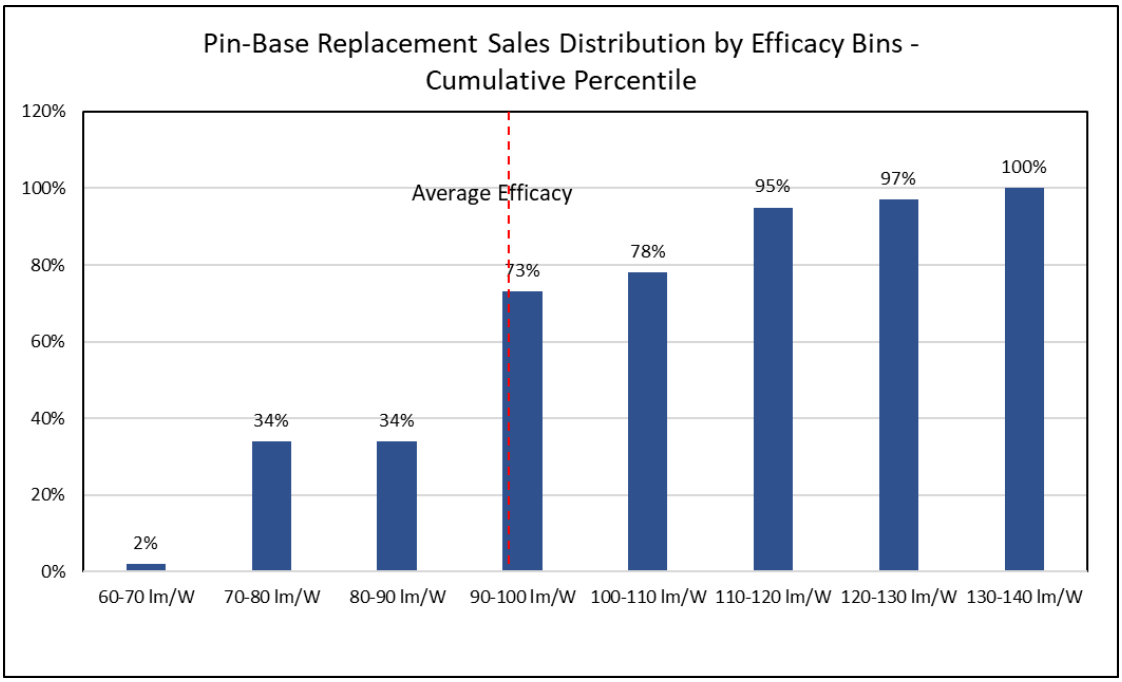
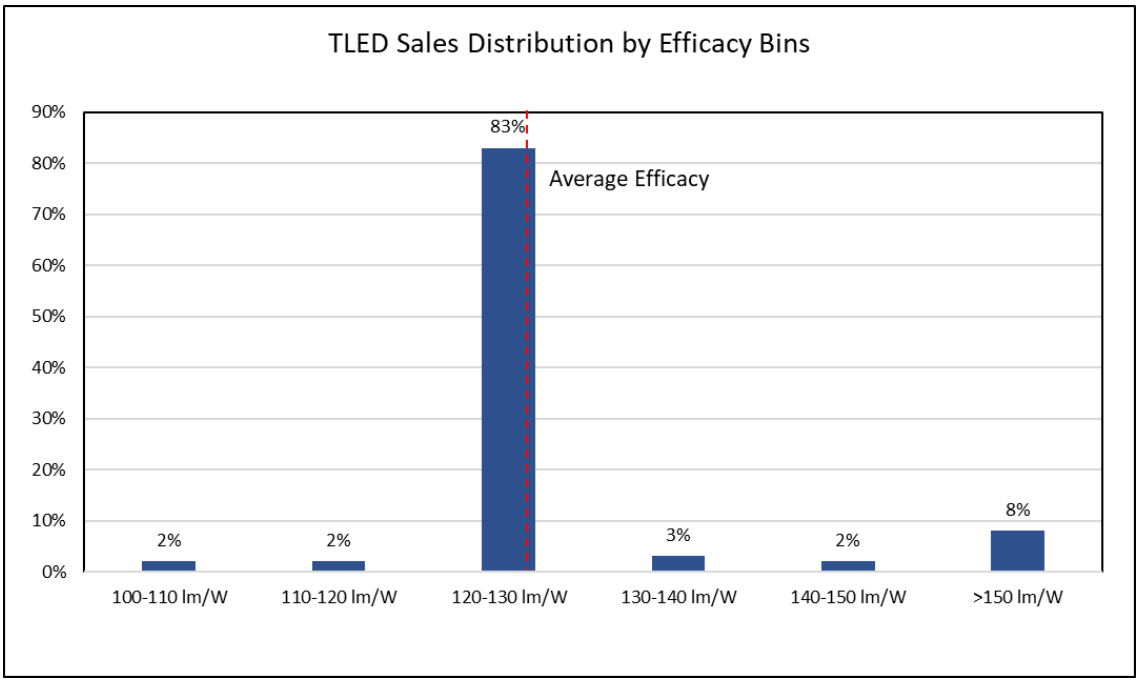


Figure 19. Pin-Based Efficacy Distribution - Cumulative Percentile



The final graph in this series is for TLEDs. This group of products had the smallest range in efficacy, with almost all products in the 120-130 lm/W range. Due to the small variability in efficacy, TRC did not create a cumulative percentile plot for this category.

Figure 20. TLED Distribution of Efficacy



Comparison to DLC Minimum Efficacy and Average Efficacy for DLC Products

Because the distributor data represented approximately 20% of the California commercial lighting market, TRC compared the efficacy values calculated here with other data available to check that results are reasonable.

As the first comparison point, TRC identified criteria and average efficacy in product databases from DesignLights Consortium (DLC) and Energy Star. (DLC does not list downlight products because they are included in Energy Star; Energy Star data is used only for downlight products in Figure 21..) Figure 21. shows the sales-weighted average efficacy values from the distributor data alongside DLC minimum efficacy values for both standard and premium certification for each product type, as well as average efficacies and the range of efficacies for each product type available in the DLC database. In most cases, the sales-weighted average efficacy from the distributor data is higher than the DLC Standard minimum efficacy, but below the DLC Premium minimum efficacy. DLC-Listed product average efficacies tend to be higher than both the sales-weighted average efficacy and the DLC Premium minimum efficacy. However, the DLC-listed product average represents an average of products *available*; these do not reflect sales, since TRC does not have sales weights to apply to DLC products. As with the distributor sales data, the range of efficacies of DLC-listed products varies widely by product type.

Figure 21. Sales Weighted Efficacies and DLC Efficacies by Product Type
(*All efficacy values for Downlight products are Energy Star criteria and database averages, as DLC does not list Downlight products.)

Product Type	Sales-Weighted Average Efficacy, 2017	DLC v4.4 Standard Minimum Efficacy	DLC v4.4 Premium Minimum Efficacy	DLC-Listed Product Average Efficacy, 2019	DLC-Listed Product Efficacy Range, 2019
1x4, 2x2, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	**115**	100	125	**133**	128 – 192
Direct Linear Ambient Luminaires	**101**	105	130	**135**	128 – 169
Linear Ambient Luminaires with Indirect Component	**94**	105	130	**117**	97 – 160
Integrated-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	**106**	100	125	**135**	102 – 178
Linear-Style Retrofit Kits for 2x2, 1x4, and 2x4 Luminaires for Ambient Lighting of Interior Commercial Spaces	**116**	100	125	**135**	102 – 178
Retrofit Kits for Direct Linear Ambient Luminaires	**123**	105	130	**135**	102 – 178
High-Bay Luminaires	**136**	105	130	**139**	96 – 216
Low-Bay Luminaires	**134**	105	130	**139**	128 – 185
Retrofit Kits for Low-Bay Luminaires	**127**	105	130	**136**	104 – 200
Downlight Luminaires	**64**	55*		**70***	50 – 138*
Downlight Retrofit Kits	**68**	60*		**72***	50 – 112*
T8/T5/T5HO Replacement Lamps	**129**	110	NA	**134**	104 – 200
Pin-Base LED Lamps for CFL replacement	**91**	75-110	NA	**90**	72 - 155

Comparison to U.S. DOE 2016 LED Product Survey

TRC also compared the distributor sales-weighted average efficacies to the results of a 2016 product survey reported in the U.S. Department of Energy's "Adoption of Light-Emitting Diodes in Common Lighting Applications" report (Navigant, 2017). The product survey determined the 5th percentile, average, and 95th percentile of efficacies of 2016 LED products, as determined from products listed in DLC, Energy Star, and DOE's LED Lighting Facts databases. (Note that DLC and Energy Star represent products that meet certain advanced performance criteria, while LED Lighting Facts is available for all LED products regardless of performance.) Figure 22, below, shows the comparison of the distributor sales data and the DOE product survey. Although the data represents two different years, the comparison helps contextualize the nature of California LED sales trends in relation to the broader LED

product market. For example, the 2017 sales-weighted average efficacies for linear products, high-bay/low-bay products, and TLEDs are on the higher end of the ranges documented in the 2016 DOE efficacy range. On the other hand, the sales-weighted efficacies for downlight products are below the average efficacy documented in the DOE product survey.

Figure 22. California Distributor Sales-Weighted Efficacies (2017) and DOE LED Product Survey Efficacies (2016)

Product Type	California Sales-Weighted Average Efficacy, 2017	DOE 2016 LED Efficacy Range		
		5th Percentile	Average	95th Percentile
Linear Luminaires/Retrofit Kits	110	70	91	118
High-Bay/Low-Bay Luminaires/Retrofit Kits	136	80	107	136
Downlight Luminaires	64	50	73	97
Downlight Retrofit Kits	68	61	76	96
T8/T5/T5HO Replacement Lamps	129	101	118	142

The comparison of these two data sets does not indicate why the sales-weighted efficacies in California skew toward the higher end of the 2016 DOE efficacy range, but it is possible that this is a reflection of the influence of utility efficiency programs driving consumers to higher performance products.

Projected Efficacy

TRC estimated efficacies through 2024 for each application type. TRC calculated efficacy projections by:

1. Assuming efficacy values for 2017 based on the Navigant distributor data
2. Projecting efficacy forward based on percent efficacy increase as estimated by the US DOE.

For the second step, TRC used LED efficacy increase projections from "Energy Savings Forecast of Solid-State Lighting in General Illumination Applications" (DOE, 2016), and created a best-fit curve to estimate annual percent increase for each relevant product type. Annual percent increase values ranged from 2.3% to 4.0% depending on the product and the year, with the highest percent increases occurring in the immediate term, and tapering off over time. TRC then applied these annual percent increase rates to the initial sales weighted efficacy for each product type from the distributor data. Additional details on the efficacy projection calculations are outlined in the Appendix. Figure 23 shows efficacy projections for each application type.

Current sales weighted efficacy values from the distributor data set already exceed previous projections from DOE for most linear product types (as shown in the Appendix). This may be because the DOE report was a national projection, while the distributor data was for California sales. Also, DOE published its report in 2016, so forecast several years into the future. However, the report (DOE, 2016) was the most reliable data source that TRC identified for developing efficacy projections; the Appendix provides more information on other studies reviewed.

Figure 23. Application Type Efficacy Projections based on Distributor Sales Weighted Efficacies

Application Type	Sales Weighted Efficacy 2017	2018 Efficacy	2019 Efficacy	2020 Efficacy	2021 Efficacy	2022 Efficacy	2023 Efficacy	2024 Efficacy
Linear Ambient Luminaires / Retrofit Kits	110	114	117	121	124	128	131	135
High-Bay/Low-Bay Luminaires / Retrofit Kits	136	140	144	148	152	156	160	164
Downlight Luminaires / Retrofit Kits	65	68	70	73	75	78	81	83
T8/T5/T5HO Replacement Lamps	129	133	137	141	145	149	152	156
Pin-Base LED Lamps for CFL replacement	91	94	96	99	101	104	106	109

Comparison to Draft Resolution Efficacy and Projection

As a comparison for current and projected efficacy, TRC reviewed the efficacy requirements and estimated improvements in efficacies as described (Draft Resolution E-5009, 2019). Table A-3 in the Draft Resolution provides the current baseline efficacies, effective August 2019, and these values are included below in Figure 24. In addition, the draft resolution states, “Historically, LED performance has improved by approximately 10-12 lm/W per year and this trend is expected to continue for at least the next five years” (Draft Resolution E-5009, 2019). Based on this statement, Figure 24 shows efficacy projections starting at the draft resolution, and assuming an 11 lm/W increase per year.

Figure 24. Draft Resolution Efficacies and Projections per Draft Resolution E5009

Application Type	Efficacy in Draft Resolution (published 2019)	2020 Efficacy	2021 Efficacy	2022 Efficacy	2023 Efficacy	2024 Efficacy
Linear Ambient	105	116	127	138	149	160
Troffer	100	111	122	133	144	155
High/Low Bay	105	116	127	138	149	160
TLED	111	122	133	144	155	166

Comparing the current efficacy results found in the distributor data (Figure 11 through Figure 20) with the efficacy assumptions (Draft Resolution E-5009, 2019) (Figure 24):

- The distributor sales-weighted efficacy (Figure 13) generally shows a higher efficacy than the draft resolution (Figure 24) for all categories. For example:
  - For linear ambient products and troffers (combined together in the distributor sales data), the Draft Resolution assumes 100 lm/W for troffers – which corresponds to the 25-percentile of distributor sales data, and 105 lm/W for linear ambient, which corresponds to somewhere between the 25- and 46-percentile. Thus, the Draft Resolution assumptions are within the range of most products.
  - For high bay/ low bay fixtures, the Draft Resolution assumes 105 lm/W, which corresponds to approximately the 3-percentile for distributor sales. For TLEDs, the Draft Resolution assumes 111 lm/W, which corresponds to between the 2- and 4-percentile. Thus, the efficacy for almost all products should meet or exceed these values.
- The draft resolution efficacy values are roughly consistent with DLC Standard minimum efficacy values for equivalent product types.

In Draft Resolution E-5009, the CPUC states, "Resolution E-4952 established a baseline of 100 lm/W for luminaires that house linear lamps by stating the following: 'Nearly all available technologies exceed an efficacy level of 100 lumens per watt. Therefore, the code/ standard practice baseline for hardwired fixtures that were not previously covered by 2018 Phase 1 dispositions shall be 100 lumens per watt'" (Draft Resolution E-5009, 2019).[2] If the CPUC intends to maintain the practice of setting a baseline that nearly all available technologies would exceed, the efficacy values the agency has identified for these product categories align with that methodology – particularly for high bay / low bay and TLEDs.

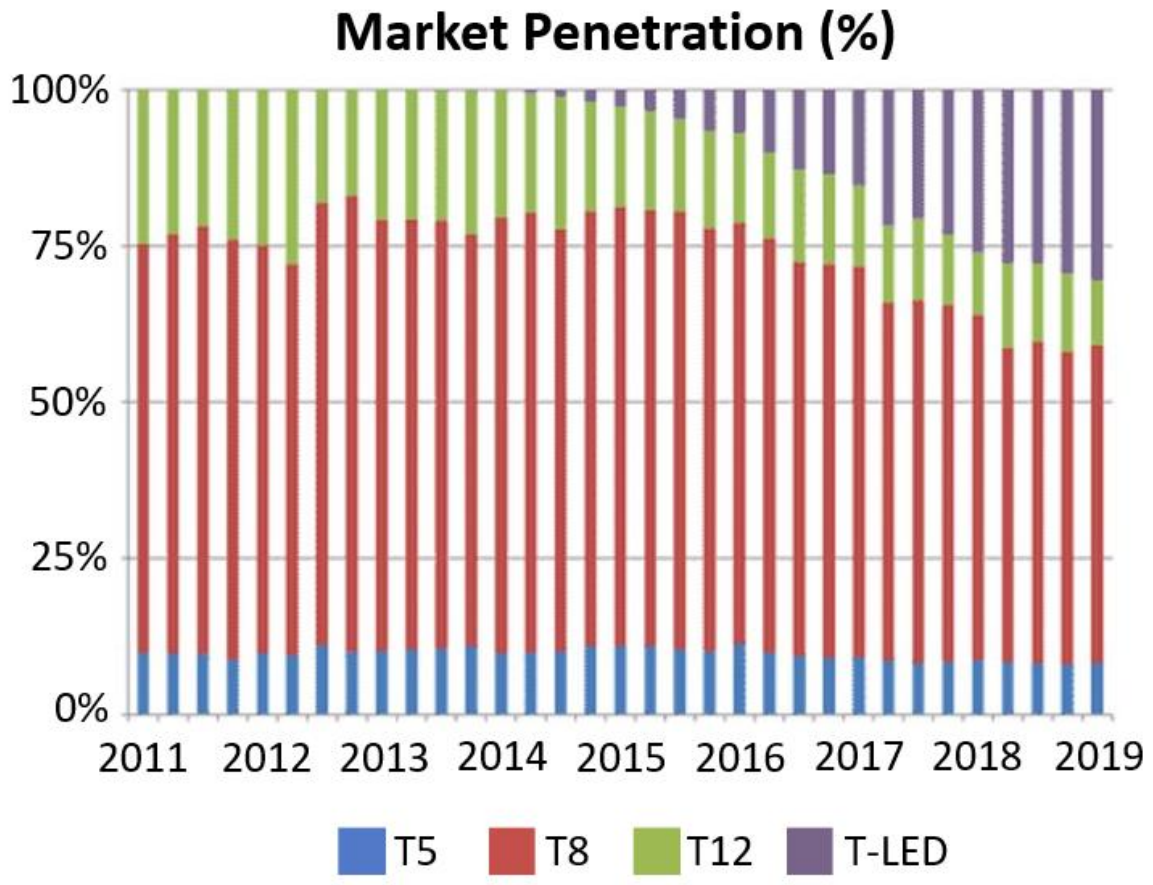
Comparing our projected efficacy from the distributor sales-weighted data and percent increase from DOE (Figure 23) with the Draft Resolution E-5009 (Figure 24): The draft resolution describes a steeper increase in efficacy improvements than DOE. Consequently, by 2024 - the project efficacies in the draft resolution for linear ambient and TLED categories are higher than the projections that TRC estimated for these categories.

[2] p. A-3 to A-4

NEMA National Shipment Data for Linear Lamps

As one other data series for context, Figure 25 provides the latest market shipment data from the National Association of Electrical Manufacturers (NEMA, 2019) for linear lamps. As shown for Quarter 1 of 2019, TLEDs (in purple) comprise 30% of linear lamps. T8 lamps (red) accounted for 51% while T5 (blue) and T12 lamps (green) claimed 8% and 10%, respectively. These shipments are for all lamps – including new construction, retrofits, and maintenance. In the Exterior Lighting Standard Practice Baseline and Work Paper Support study, TRC found in interviews with manufacturers, sales representatives, and contractors that almost all (94%) of commercial projects install LEDs for new construction and retrofit projects, but most use incumbent (generally high intensity discharge – HID or fluorescent) technologies for maintenance (i.e., replacement of only failed lamps and ballasts) (TRC, 2018). If the same trend is true for interior lighting, and if the trends found for California are similar to national trends, it is likely that many of the LED shipments in Figure 25 are for new construction and retrofits, while most of the fluorescent shipments are for maintenance. Interviewees also reported in the Exterior Lighting Standard Practice Baseline and Work Paper Support study that the primary reason why customers choose to maintain their existing system instead of retrofitting their system with LEDs is incremental cost.

Figure 25. Linear Lamp Shipments from National Electrical Manufacturers Association (NEMA)



Conclusions

This analysis of sales weighted efficacies and efficacy projections indicates that:

- The Draft Resolution E-5009 efficacy values for linear LED products are at the low end of the range of efficacies found in the distributor data, and lower than the sales-weighted average efficacy values from the distributor sales data set. Lower disposition values allow for flexibility in consideration of other performance metrics such as color temperature and CRI. Also note that the distributor data includes program sales, which likely inflates the average efficacy.
- Draft Resolution E-5009 efficacy values are roughly consistent with DLC Standard minimum efficacy values for equivalent product types.
- Sales weighted average efficacy values from the 2017 distributor sales data set appear to be relatively consistent with the average efficacy values from the DLC-listed product database.

Program Manager and Implementer Interview Findings

TRC conducted interviews with three program managers (one from each electric IOU[3]) and two lighting program implementers – both of whom serve customers across the State. TRC requested interviews from additional implementers and offered $75 gift card for participation in a 30-minute phone interview, but the other implementers declined the request.

While this represents a small number of interviewees, the purpose was to check that the results of the sales split (fixtures vs. retrofit kits vs. TLEDs) appeared reasonable since few published studies were available for comparison, and to provide context to the distributor data results. Thus, TRC did not use these interviews to develop quantitative assumptions.

TRC found that:

- All interviewees felt that the split of TLED, luminaire, and retrofit kit sales outlined above appeared to be an accurate reflection of overall lighting product sales.
- All interviewees felt that the lamps per luminaire assumptions (2.5 lamps per linear luminaire average; 1.3 lamps per downlight luminaire average) were reasonable.
- All interviewees reported that cost is the primary driver for customer decision-making. Most interviewees did not name any other factors in decision-making. One mentioned that in rare cases attention to light quality or design may also impact customer choices.

[3] For one electric IOU, the program manager interviewed served the residential lighting program, because the nonresidential lighting program manager was not available for an interview.

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REFERENCES

BPA. (2017). *Non-Residential Lighting Market Characterization.* https://www.bpa.gov/EE/Utility/research-archive/Documents/Momentum-Savings-Resources/2017_NonResidential_Lighting_Final_Report.pdf.

DLC. (2018). *Energy Savings Potential of DLC Commercial Lighting and Networked Lighting Controls.* Retrieved from https://www.designlights.org/default/assets/File/DLC_Energy-Savings-Potential-of-DLC-Commercial-Lighting-and-Networked-Lighting-Controls.pdf

DLC. (n.d.). *Product Eligibility/Primary Use Designations.* Retrieved from https://www.designlights.org/solid-state-lighting/qualification-requirements/product-eligibility/

DOE. (2014). *Energy Savings Forecast of Solid-State Lighting in General Illumination Applications.* Retrieved from https://www.energy.gov/sites/prod/files/2015/05/f22/energysavingsforecast14.pdf

DOE. (2016). *Energy Savings Forecast of Solid-State Lighting in General Illumination Applications.* https://www.energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf.

DOE. (2017). *Solid-State Lighting 2017 Suggested Research Topics.* Retrieved from https://www.energy.gov/sites/prod/files/2017/09/f37/ssl_suggested-research-topics_sep2017.pdf

(2019). *Draft Resolution E-5009.* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M309/K679/309679758.PDF.

Itron Inc. (2014). *California Commercial Saturation Study (CSS) .* Retrieved from http://calmac.org/publications/California_Commercial_Saturation_Study_Report_Finalv2.pdf

Navigant. (2017). *Adoption of Light-Emitting.* Retrieved from https://www.energy.gov/sites/prod/files/2017/08/f35/led-adoption-jul2017_0.pdf

Navigant. (2018). *California Statewide Non-Residential LED Quality and Market Characterization Study.* Retrieved from http://calmac.org/publications/CA_NR_LED_Qual_Pt_2_Final_Report.pdf

NEMA. (2019). *Linear Fluorescent Lamp Indexes Continue Year-Over-Year Decline in First Quarter 2019 while T-LED Market Penetration Increases.* https://www.nema.org/Intelligence/Indices/Pages/Linear-Fluorescent-Lamp-Indexes-Continue-Year-Over-Year-Decline-in-First-Quarter-2019-while-T-LED-Market-Penetration-Increa.aspx.

TRC. (2018). *Exterior Lighting Standard Practice Baseline and Work Paper Support – Final Report.* Retrieved from http://www.calmac.org/publications/TRC_-_SCE_Ext_Lighting_SP_and_WP_Support_Final_Report.pdf

APPENDIX: DATA SOURCES

Lamp and Luminaire Sales Data

As described in the body of the memo above, Navigant provided TRC with the results of their distributor sales data analysis for the California Statewide Non-Residential LED Quality and Market Characterization Study (Navigant, 2018). Navigant collected sales data from three distributors, representing approximately 20% of the state lighting market, and then applied scaling and adjustment factors by product type to estimate the scale and performance characteristics of statewide LED product sales for 2017. These statewide estimates are the data presented in the body of the memo.

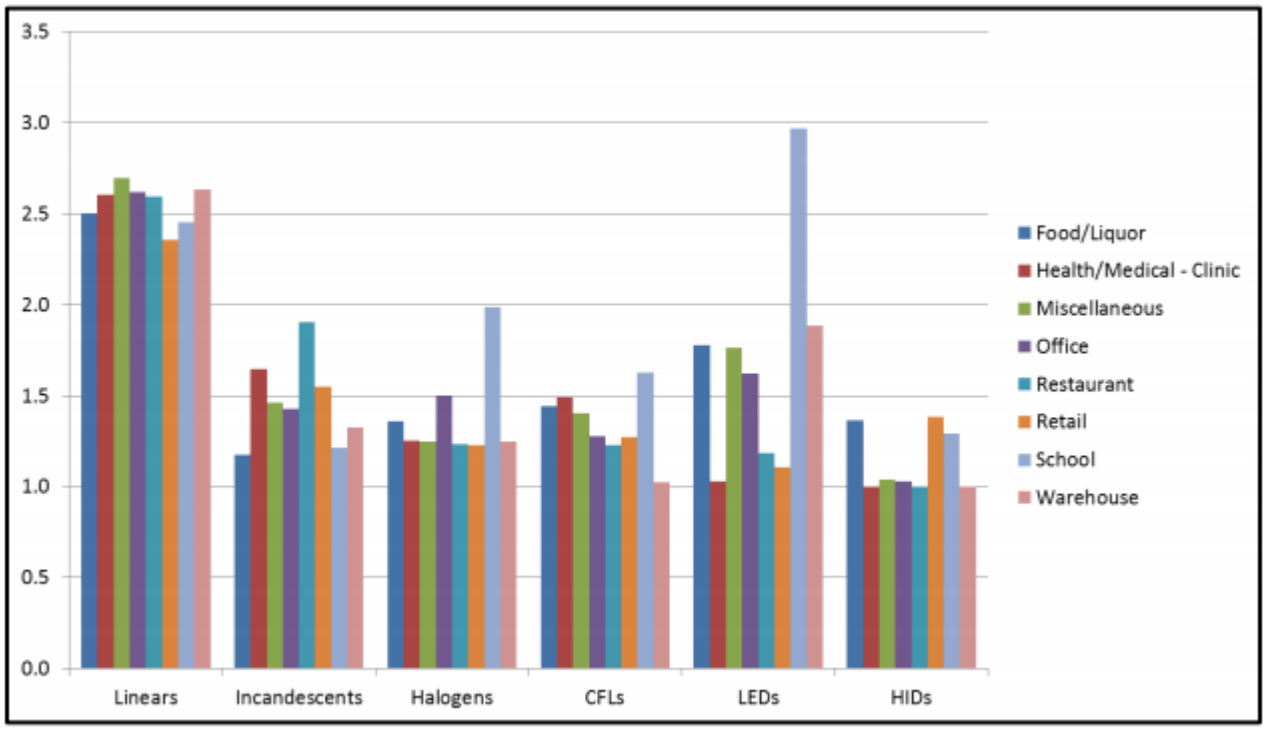
TRC asked Navigant to provide some additional information about how representative the distributor data was, and how much variation there was in the efficacies of products sold by each of the distributors. Navigant reported that across all product types, the percent difference between the overall sales-weighted average efficacy and the sales-weighted averages for each distributor and product type ranged from 0% to 18% difference. The average percent difference was 5%, and over 75% of the differences were less than 10%, indicating that in most cases each distributor's efficacy ranges were close to the overall sales-weighted average for each product, and relatively consistent between distributors.

In addition to the overall sales and efficacy data, Navigant also estimated the market share of DLC and Energy Star products. The analysis of 2017 California sales found that a total of 55% of eligible products were DLC-listed (41% DLC Standard and 14% DLC Premium), and 80% of downlight products were Energy Star certified.

Lamps per Luminaire Estimations

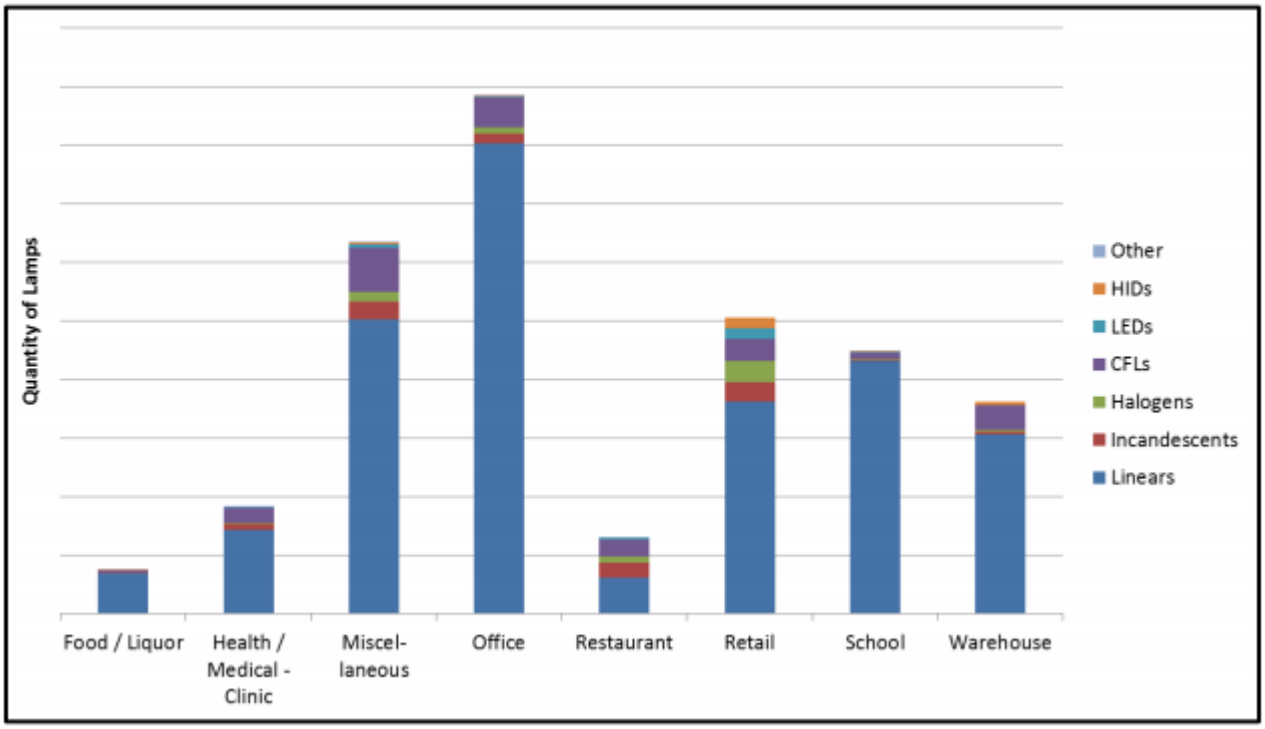
To estimate the proportion of luminaires impacted by LED lamp replacement sales, TRC estimated the average number of lamps per luminaire for both linear and downlight luminaire products, based on data reported in the California CSS (Itron Inc., 2014). Figure 26 shows average lamps per luminaire by lamp type and building type. Estimates of lamps per luminaire in the linear products above are based on the "Linears" category in this table, while estimates for the downlight products are based on the "CFLs."

Figure 26. Average Number of Lamps per Fixture – Indoor Lighting (reproduced from California Commercial Saturation Survey, Figure 5-5)



For the number of lamps per linear fixture, TRC used the simple estimate of 2.5 lamps based on the CSS, since that figure shows little variation by building type. For lamps installed as downlights (including incandescents, halogens, and CFLs), Figure 27 shows more variation in number of lamps per fixture. Consequently, to develop an estimate of lamps per luminaire for downloads, TRC used the distribution of lamp types shown below in Figure 27 to estimate building-type-weighted average values.

Figure 27. Distribution of Lamps by Technology Type and Business Type – Indoor Lighting (reproduced from California Commercial Saturation Survey, Figure 5-2)



Efficacy Projection Calculations

This section describes the process TRC used to calculate efficacy projections. As a starting point, TRC used the sales-weighted average efficacy results for each group of products for 2017, presented in Figure 11. TRC then projected those values forward to 2023, by determining best fit curves based on published studies and interpolating to the years of interest to determine percentage efficacy increase for each year.

Figure 28 provides the efficacy projections for different categories of LED lamps and luminaires (DOE, 2016). These projections use the rate of efficacy increase from the same DOE report. The efficacy projections in that report are based on the method from SSL Pricing and Efficacy Trend Analysis for Utility Program Planning report prepared by Pacific Northwest National Laboratory (PNNL) for the DOE in October 2013. The projections were calculated using publicly available data through December 31st, 2015 (DOE, 2016).

Figure 28. National LED Efficacy Projections (DOE 2016)

Submarkets	LED Luminaire Efficacy				
	2015	2020	2025	2030	2035
Linear Ambient Fixtures	99	123	142	158	171
High-Bay/Low-Bay Luminaires	100	121	138	152	164
Downlights	77	101	120	135	148
TLED Linear LED	112	137	157	174	187
Pin-Base Replacements for CFLs	67	81	92	101	108

Figure 29, Figure 30, and Figure 31 show TRC's calculated mean efficacy projections and annual percent increases for each group of products, based on the DOE projections shown in Figure 28.

Figure 29. LED Efficacy Projections for 2019-2023, Linear Ambient Fixtures and High/Low Bay Luminaires

Product Category	Linear Ambient Fixtures		High-Bay/Low-Bay Luminaires	
	Efficacy	Percent Increase	Efficacy	Percent Increase
2017	110		110	
2018	114	3.3%	113	2.9%
2019	117	3.2%	116	2.8%
2020	121	3.1%	119	2.7%
2021	124	3.0%	122	2.7%
2022	128	2.9%	125	2.6%
2023	131	2.8%	129	2.5%
2024	135	2.7%	132	2.5%
2025	139	2.7%	135	2.4%

Figure 30. LED Efficacy Projections for 2019-2023, Downlights and TLED Linear LEDs

Product Category	Downlights		TLED Linear LED	
	Efficacy	Percent Increase	Efficacy	Percent Increase
2017	88		123	
2018	92	4.0%	127	3.0%
2019	95	3.8%	131	2.9%
2020	99	3.7%	135	2.9%
2021	102	3.6%	138	2.8%
2022	106	3.4%	142	2.7%
2023	109	3.3%	146	2.6%
2024	113	3.2%	150	2.6%
2025	116	3.1%	153	2.5%

Figure 31: LED Efficacy Projections for 2019-2023, Pin Based Replacements for CFLs

Product Category	Pin-Base Replacements for CFLs	
	Efficacy	Percent Increase
2017	73	
2018	76	2.8%
2019	78	2.7%
2020	80	2.6%
2021	82	2.6%
2022	84	2.5%
2023	86	2.4%
2024	88	2.4%
2025	90	2.3%

TRC then used the annual percent increases to determine the efficacy projections shown above in Figure 23 (in the main body of the memo). In other words, for each product category, TRC:

1. Started with the efficacy levels shown in Figure 11 (in the main body of the memo) that are based on the 2017 distributor data set from Navigant, and then
2. Applied the percentage efficacy increase for the appropriate product category shown in and Figure 29, Figure 30, and Figure 31 for each year.

As a caveat to findings, the estimates provided in the DOE (2016) are three years old. TRC reviewed additional resources for other potential efficacy projections, but those referenced back to the DOE projections. In addition:

- 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 (DOE, 2017). That report does not include luminaire efficacy, but only the efficacy of the LED chip package, so these values are not meant to be directly comparable to the efficacy of the luminaire types in Figure 28 above. TRC chose not to calculate efficacy projections based on this source because it is only relevant to LED chip packages.
- The DOE also published a report with efficacy projections in 2014 (DOE, 2014). The rate of efficacy increase provided in the more recent DOE report used here (DOE, 2016) are similar to – but slightly lower than - those in the older report (DOE, 2014).

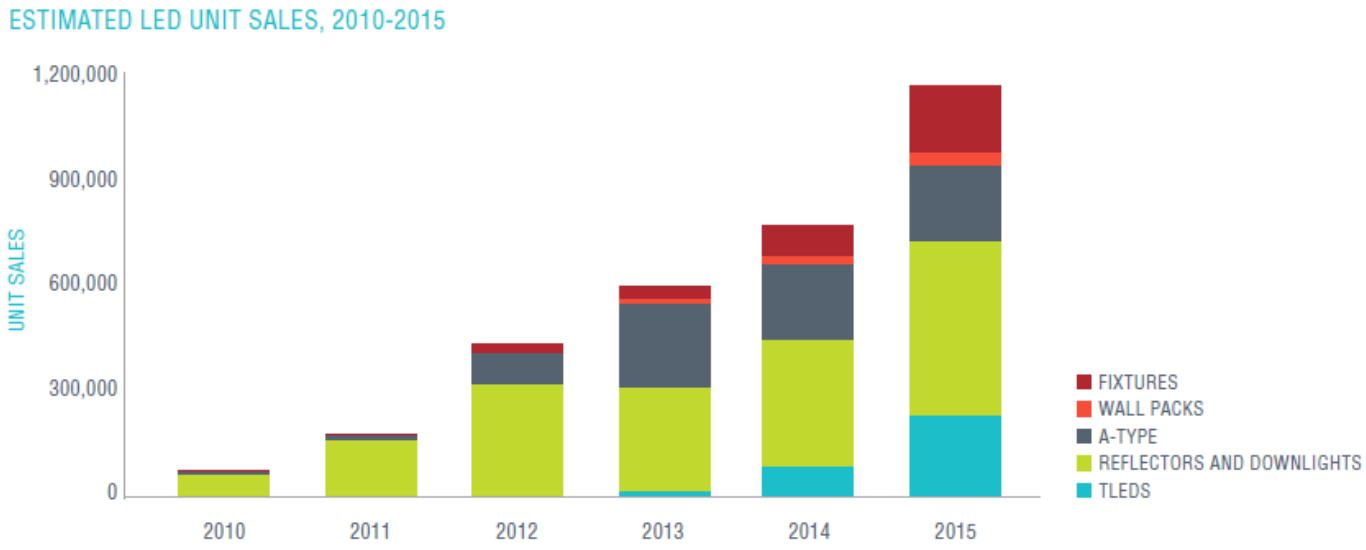
BPA 2016 Non-Residential Lighting Market Characterization

Bonneville Power Authority's (BPA) 2016 Non-Residential Lighting Market Characterization, prepared by Navigant, provides some data on LED sales similar to the research questions of this study (BPA, 2017). Differences in policy and program priorities in BPA territory (Washington, Oregon, Idaho, and Montana) mean that the results of this report are not directly comparable to the California market, but there are some similarities in overall trends.

Figure 32 shows LED unit sales in BPA territory by product type for 2010-2015. TRC interpreted the "fixtures" category (the red bar) as linear ambient fixtures, since other fixture types are presented separately – e.g., reflectors and downlights. In addition, because this figure does not present results separately for retrofit kits, TRC assumed that these would also be included within the "fixtures" category. Based on a visual comparison of the sales of fixtures (red bar) and TLEDs (blue bar), TRC estimated that the study found that approximately 45% of linear sales were linear fixtures (including retrofit kits) and 55% were TLEDs for 2015.

Though downlight and reflector type products make up the largest proportion of sales, TLEDs are the fastest growing product type in the years between 2013-2015. The "fixtures" (i.e., linear ambient) category, also grows quickly in the year from 2013-2015. These market shifts in product type unit sales may also reflect advances in technology that make TLED and linear fixtures more viable for customers, as reflected in the more current California distributor data.

Figure 32. Estimated LED Unit Sales, 2010-2015 [Reproduced from Non-Residential Lighting Market Characterization (BPA, 2017)]



Similarly, as shown below in Figure 33, TLEDs make up the largest share of program incentivized products in BPA territory from October 2014-September 2015. However, as noted above, program trends in BPA territory are not directly comparable to the California market due to different regulatory and program policies.

Figure 33. Count of Lamps Sold Through Program, by Wattage and Type [Reproduced from Non-Residential Lighting Market Characterization (BPA, 2017)]

Technology	0–29W	30W–39W	40W–49W	50W–99W	>100W	Total	% of Total
TLED	46,449	434	0	0	2	**46,885**	**28%**
LED Small Lamp/Fixture	40,398	758	452	290	1	**41,899**	**25%**
T8	7,669	18,404	0	0	0	**26,073**	**17%**
LED Exterior	3,403	1,207	4,272	6,537	5,597	**21,016**	**13%**
T5	0	0	2,130	10,202	0	**12,332**	**6%**
LED Troffer	440	1,074	1,945	641	0	**4,100**	**2%**
LED High Bay	0	0	12	349	3,093	**3,454**	**2%**
Other	8,101	381	77	85	439	**9,083**	**6%**
Total	**106,460**	**22,258**	**8,888**	**18,104**	**9,132**	**164,842**	**100%**

Source: Navigant and Cadeo analysis of BPA commercial and industrial lighting program data (extracted November 15, 2015; time period analyzed October 2014–September 2015)