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Compilation of Data to Inform the LED A-lamp Baseline

Final White Paper

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1. INTRODUCTION AND SOURCES

1.1 Purpose

Pacific Gas and Electric Company (PG&E) requested that TRC Energy Services (TRC) compile data to inform light emitting diode (LED) A-lamp baseline assumptions. The purpose of this assignment was to support current LED A-lamp work paper updates for 2017 and possibly beyond. This white paper provides sales estimates, lamp availability data, data indicating the lamp technologies consumers replace with LEDs, and installed lamp data. Because the LED A-lamp work paper applies to both residential and nonresidential LED installations, TRC gathered data for residential and nonresidential buildings.

1.2 Summary of Sources

TRC reviewed several data sources that could inform LED A-lamp baseline assumptions.

- All data sources are specific to California, except for data from the National Electrical Manufacturers Association (NEMA).
- Some data sources are specific to A-lamps, while others include all screw-based lamp types (A-lamps, reflectors, globes, and candelabras). Data for tubular lighting (e.g., T8s) are not included.
- Several data sources are specific to residential buildings, while other data sources provide shipping or shelf survey data that could be purchased for residential or nonresidential buildings. However, field surveys have found that most A-lamp and screw-based lamps are installed in residential buildings[1]. The Commercial Saturation Survey (CSS) is the only source specific to nonresidential buildings.

Section 3 provides the references for each data source, and Section 4 (Appendix A – Detailed Results) describes the methodology and results.

TRC organized the data sources into the following categories:

Lamp sales estimates:

- Sales estimates from LightTracker. These represent all lamps purchased in California in 2015, including A-lamps, reflectors, globes, and other lamp types. LightTracker develops its estimates based on actual point-of-sales (POS) data from some channels; for the remaining (non-POS) channels, the LightTracker report extrapolates purchases from a sample of consumers that scan their purchases. Because the non-POS data represents only residential sales, TRC adjusted the POS data to reflect residential sales only. The Appendix B – LightTracker Methodology describes the LightTracker methodology, and Section 4.1 describes TRC's adjustment to reflect only residential sales.
- TRC estimates of lamp sales, from adjusting the winter 2015/16 shelf survey based on consumer purchasing preferences. The shelf survey reflects the number of lamps available for purchase. DNV-GL conducted the shelf survey from November 2015 to January 2016. TRC used results of a consumer phone survey question[2] that asked consumers which channels they recently purchased lamps to develop

[1] The most recent upstream lighting program (ULP) impact evaluation assumes that 93% of rebated lamps are installed in residential buildings and 7% in nonresidential buildings (DNV-GL 2017), based on findings from the residential survey, California Lighting and Appliance Saturation Survey (CLASS – DNV-GL 2014a), and the Commercial Market Share Tracking Study (Itron 2014a).

[2] The phone survey was also conducted by DNV-GL, and presented in the reference DNV-GL 2016a.

sales multipliers, and then applied the sales multipliers to the shelf survey data to estimate lamp purchases. Section 4.2 describes the methodology and full results of this approach.

Lamp availability data:

- Results for A-lamps from the winter 2015/16 shelf survey. As described above, DNV-GL conducted the retailer shelf survey from November 2015 to January 2016. The results reflect a "snapshot in time" of lamp availability.
- U.S. shipments of A-lamps according to National Electrical Manufacturers Association (NEMA). NEMA is a trade organization that includes lamp manufacturers, and it provides quarterly data of U.S. A-lamp shipments. Although data is only available at the national level, this source illustrates the rapid changes in the residential lighting market.

Lamp replacement data:

- Consumer intercept survey results of what lamp technologies were replaced by LEDs (DNV-GL 2016a). As part of a consumer intercept survey conducted in the winter 2014/15, DNV-GL asked consumers what lamp technologies they intended to replace with the LEDs they were purchasing.
- Consumer phone survey of what lamp technologies were replaced by LEDs (DNV-GL 2017). As part of the Impact Evaluation of 2015 Upstream and Residential Downstream Lighting Programs, DNV-GL conducted a telephone survey, which included a question of what lamp technologies consumers replaced with their recently purchased LEDs.

Installed lamp data:

- California Lighting and Appliance Saturation Study (CLASS 2012 - DNV-GL 2014a). CLASS was an on-site study conducted in residential buildings the second half of 2012. Results show the lamps installed in California homes during that time.
- The California Commercial Saturation Survey (CSS – Itron 2014b). CSS was an on-site study conducted in commercial buildings the first quarter of 2012 through the fourth quarter of 2013. Note this is the one data source that is specific to commercial buildings.

2. Summary of Findings

Figure 1 presents a summary of results from the different data sources. Traditionally, impact evaluations have not included LEDs in the baseline, because the net savings adjustment has accounted for participants that would have purchased LEDs in the absence of the program – i.e., free riders. However, the most recent impact evaluation of the Upstream Lighting Program (ULP) (DNV-GL 2017) had two net savings adjustments – an adjustment for free ridership (the "net-to-gross quantity" adjustment, or NTGRq) and an adjustment to account for differences in energy savings between the lamps installed and the lamps available for purchase (the "net-to-gross unit energy savings" adjustment, or NTGRu). Consequently, Figure 1 shows:

- The percent of all technologies, including LEDs, to align with the most recent ULP impact evaluation methodology, shown in the gray shaded cells; and
- The percent of halogens and incandescent lamps ("Incand + Halogen") compared with CFLs after removing LEDs, to align with traditional impact evaluation practices, shown in the green shaded cells.

Figure 1. A-Lamps by Technology: Comparison across Data Sources

Description of Data Source			All Technologies				After Removing LEDs	
Source	**Description**	**Data Timeframe**	**Incand**	**Halogen**	**CFL**	**LED**	**Incand + Halogen**	**CFL**
Sales Estimates								
LightTracker (Apex Analytics): all lamps (A-lamps, reflectors, etc.)	All Lamp Sales Estimates, Res	2015	11%	31%	22%	36%	66%	34%
TRC estimate of A-lamp sales, based on DNV-GL winter 2015/16 shelf survey	A-lamp Sales Estimates, Res	Late 2015/early 2016	11%	24%	29%	36%	55%	45%
Available Lamps								
NEMA U.S. shipment data, average of last four quarters	A-Lamps Shipped, Res & Nonres	Q4 2015 through Q3 2016	10%	48%	18%	24%	77%	23%
DNV-GL CA winter 2015/16 shelf survey data for A-lamps	A-Lamps Stocked, Res & Nonres	Nov. 2015-Jan. 2016	18%	30%	34%	18%	58%	42%
Lamps Replaced by LEDs								
Consumer intercept survey question: For A-lamps, what lamp technologies they planned to replace with LEDs (DNV-GL 2016a)	A-lamps Replaced, Res	Nov. 2014-Jan. 2016[3]	43%	5%	49%	2%	49%	51%
Consumer phone survey question: What lamp technologies they had replaced with LEDs (DNV-GL 2017)	All Lamps Replaced, Res	2015	51%	14%	30%	5%	68%	32%
Installed Lamps								
CLASS 2012 (DNV-GL 2014a): Installed A-lamps	A-Lamps Installed, Res	May – Nov 2012	48%	0.2%	49%	2%	50%	50%
CSS (Itron 2014b): Installed Medium Screw Based (MSB) Lamps	MSB Lamps Installed, Nonres	Q1 2012 – Q4 2013	30%	9%	53%	7%	43%	57%

[3] Combines results of the winter 2014/15 and winter 2015/16 retailer shelf surveys.

Figure 1 indicates the following:

Sales estimates:

- In general, the sales estimates indicate that CFLs comprise about one-quarter (22-29%) of A-lamp purchases with LEDs, and less than half (34-45%) of A-lamp purchases without LEDs.
- Both sales estimates are the same for incandescent lamps (11%) and LEDs (36%) when all lamp technologies are included. There is more divergence for halogens and CFLs, but results are still fairly close, showing that halogens comprised 24-31% and CFLs comprised 22-29% of A-lamps when all lamp technologies are included. The TRC CFL estimate may be higher because our estimate is for A-lamps only, where CFLs have had the most penetration[4]. In contrast, the LightTracker estimate includes all lamps, and CFLs have had lower penetration for reflectors and globe lamps.

Lamp availability:

- The two sources indicate that CFLs comprise approximately one-third or less of all available A-lamp technologies (18-34%) when all technologies are considered, and less than half (23%-42%) after removing LEDs.
- When all lamp technologies are included, the U.S. NEMA shipment data shows higher halogen and LED lamp availability and lower incandescent and CFL lamp availability compared with the California shelf survey. This could be at least partially due to differences between U.S. and California stocking preferences: LightTracker 2015 sales estimates for California compared with the U.S. (not shown) indicate that incandescent and halogen lamps comprised a lower percent of sales in California (43%) than in the U.S. (57%). The discrepancy in results between the LightTracker and TRC estimate could also be attributed to the different data collection timeframes. The NEMA results in Figure 1 reflect the most recent four quarters (Q4 2015 – Q3 2016). As shown in Figure 11 (Section 4.3), NEMA data for a comparable period as the winter 2015/16 shelf survey show that LEDs comprised 16% (in Q4 2015) and 26% (in Q1 2016) of total shipments, which are similar to the 18% found in the winter 2015/16 shelf survey.
- Focusing on the California specific data from the winter 2015/16 shelf survey, when all lamp technologies are included, CFL availability is slightly higher in the shelf survey data (34%) compared with the lamp sales estimates (22-29%) when all technologies are included. When LEDs are removed, CFLs comprise 42% of lamps in the shelf survey, which is in the range of the sales estimates (34-45%).

Lamps replaced by LEDs:

- Based on the consumer intercept survey, which asked specifically about A-lamps, LEDs are replacing approximately half CFLs (49%), with the remainder primarily replacing incandescent (43%) and halogen lamps (5%).
- The fraction of lamps that LEDs replace that are CFLs was lower in the phone survey (30%, before removing LEDs), which asked about all lamp types. One reason for the discrepancy could be because CFLs comprise a smaller fraction of reflectors and globes than A-lamps, as noted above.
- LED-to-LED replacements were fairly low for both surveys (2-5%). However, given the low penetration of LEDs among installed lamps (2% in CLASS 2012) and their long measure life, this may indicate some

[4] Of the CFLs found in CLASS 2012, 80% were A-lamps, 9% were reflectors, and 3% were globe lamps (DNV-GL 2014b, Table 27).

dissatisfaction with initially installed LEDs. This would be surprising, since the recently conducted DNV-GL (2017) consumer phone survey generally found high satisfaction with LEDs.

Installed lamps:

- Based on CLASS, CFLs comprised approximately half of lamps installed in residential buildings (49% before removing LEDs). Because CLASS was conducted in 2012, there was low penetration of LEDs, so results are similar without LEDs. From 2012 to the present, lamp availability data have shown increases in halogens and LEDs, and decreases in incandescent lamps[5]. See the NEMA trends in Figure 10 (Section 4.3) and the California shelf survey trends in Figure 14 (Section 4.4) for past lamp availability. Thus, a more recent survey of installed lamps would likely show higher penetration of halogens and LEDs, and lower incandescent penetration. TRC also hypothesizes that CFL installation has decreased since 2012, since the DNV-GL California shelf surveys show that the fraction of A-lamps comprised by CFLs has decreased (Figure 14). However, the CFL trend is not as clear as the trends for other technologies, since the national data from NEMA (Figure 10) shows that CFL shipments increased slightly through 2014, but have declined significantly since.
- For nonresidential buildings, the CSS found that (after removing LEDs) CFLs comprised 57% of medium screw-based (MSB) lamps, with incandescent and halogen lamps comprising the remainder (43%). However, the CSS was conducted 2012-2013. Since commercial interior CFLs have an Effective Useful Life (EUL) of 4.7 years or less (DEER 2016), most of the lamps observed in CSS should have been replaced. TRC hypothesizes that a more recent nonresidential survey would have similar trends as described in the bullet above for residential buildings: more halogens and LEDs, fewer incandescent lamps, and probably fewer CFLs.
- The CFL results are similar for installed lamps (CLASS 2012) and the lamps consumers planned to replace with LEDs (consumer intercept survey). The consumer intercept survey result found that approximately half of the recently purchased LED A-lamps would replace were CFLs, which is the same fraction of installed A-lamps that were CFLs (49% were CFLs in CLASS 2012). The fraction of installed A-lamps that were CFLs (49%) was higher compared with the phone survey response to what lamp technologies recently purchased LEDs replaced for all lamps (30%). The differences could be attributed to differences in preferences by lamp types (A-lamps vs. reflectors and globes), or other reasons.

In summary, these results indicate:

- After removing LEDs, **CFLs comprise less than half of purchased or available A-lamps, with the California sources showing that CFLs comprise 34-45%** (based on the LightTracker sales estimate, TRC estimate of A-lamp sales, and California shelf survey result). Halogens comprise the majority of the remaining lamps sold or available, although incandescent lamps persist (comprising 10%-18% of all lamps sold or available, when LEDs are included in the analysis).
- **CFLs represented approximately half of the A-lamps replaced by LEDs, and about half of installed lamps.** The majority of the remaining LEDs were replacing incandescent or halogens. The phone survey indicated a lower percent (30%) of CFLs replaced by LEDs. However, the phone survey question covered all lamp types, so TRC believes that the intercept survey (though conducted with a smaller population) is

[5] The halogen increase and incandescent lamp decrease may at least partially be due to the Energy Independence and Security Act (EISA), which phased out traditional incandescent A-lamps in common lumen bins, with an effective start date of 2011-2013 in California.

more accurate for A-lamps.[6] CLASS (2012) indicated that approximately half of installed A-lamps were incandescent and the other half CFLs, although this data source is from 2012.

- **After removing LEDs, for installed lamps, CFLs comprise slightly more than half (57%) of lamps in nonresidential buildings**. The data in CSS was collected 2012-2013, so may not reflect the current installed base.

The recent Impact Evaluation of 2015 Upstream and Residential Downstream Lighting Programs (DNV-GL 2017) found that approximately two-thirds of LEDs are replacing functioning lamps.[7] Consequently, the LED baseline could be based on a blend of sales and availability data (representing LEDs installed through replace-on-burnout), and the installed lamp data (representing LEDs installed through early retirement).

3. REFERENCES

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[6] In the intercept survey, CFLs comprised a smaller percent of reflector lamps replaced by LEDs (28%), but a larger percent of globe lamps replaced by LEDs (63%), compared with CFL A-lamps replaced by LEDs (49%). These numbers have been adjusted to remove empty sockets and "Don't know" responses.

[7] P. 117: Among LED purchasers, approximately 68% reported they replaced lamps that were still functioning, and 32% replaced lamps that had burned out (after removing respondents that could not recall the condition of the replaced lamp).

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4. APPENDIX A – DETAILED RESULTS

This section provides detailed results for each data source. When presenting results, TRC rounded to the nearest whole number or percentage.

4.1 LightTracker Results

Apex Analytics developed the LightTracker sales report from two sources: point-of-sale (POS) state sales data, representing the grocery, drugstore, discount, and mass merchandise channels, and some membership club retailers; and National Consumer Panel (NCP) state sales data, representing the home improvement and hardware channels, and the remaining membership club retailers. Section 5 - Appendix B – LightTracker Methodology describes in more detail how Apex Analytics developed the LightTracker sales report.

TRC made one minor adjustment to the LightTracker sales report. The POS sales data represented all lamp sales (for lamps installed in both residential and nonresidential buildings), while the non-POS sales data represented residential sales only. TRC multiplied the lamp POS sales estimate by 93% to reflect residential lamp sales only[8], and then combined this residential POS sales estimate with the non-POS estimate. The result is an estimate of residential lamp sales only, as opposed to a hybrid of residential (non-POS) and residential + nonresidential (POS) results from the unadjusted LightTracker report. Note that, because the majority of purchases were in the non-POS channels, and because the residential multiplier was 93%, this was a very small adjustment (shifted the sales percentage of each technology by ≤ 1%). TRC could not use the LightTracker report to develop a nonresidential lamp sales estimate, since there is no similar entity to the NCP for estimating commercial purchases in non-POS channels.

Figure 2 shows estimates of residential sales by lamp technology based on the LightTracker report[9] for California for 2015. Because the LightTracker report is confidential, we provide relative values, rather than results in absolute numbers of lamps.

Figure 2. LightTracker Residential Sales Estimates for CA for 2015

Type	% of Sales	% of Sales, after Removing LEDs
Incandescent	11%	18%
Halogen	31%	48%
CFL	22%	34%
LED	36%	
Total	100%	100%

[8] Based on the residential / nonresidential split shown in DNV-GL 2017.

[9] The information contained herein is based in part on data reported by LightTracker through its Advantage service for, and as interpreted solely by LightTracker Inc. Any opinions expressed herein reflect the judgment of LightTracker Inc. and are subject to change. LightTracker disclaims liability of any kind arising from the use of this information.

4.2 TRC Sales Estimates based on DNV-GL Shelf Survey Data

4.2.1 Methodology for TRC Sales Multipliers

Purpose of Multipliers

TRC developed the sales multipliers because the shelf surveys indicate lamp availability on retailers' shelves, not sales. Lamps may be sold in greater volume through some channels (e.g. big box retail) than through other channels (e.g. grocery stores) due to different lamp sell through rates[10]. TRC accounted for this discrepancy by developing the sales multipliers, which amplify the sales impact of the respective channel to more accurately reflect the channel sales volume.

The motivation for the multipliers is illustrated in Figure 3, which compares the percent of A-lamps in the winter 2015/16 shelf survey by channel (weighted by DNV-GL to account for their sampling of store channels), with where consumers reported they recently purchased lamps in a phone survey (DNV-GL 2016a).

Figure 3. Lamps by Channel in Winter 2015/16 Shelf Survey Compared with Consumer Purchasing Preferences

	Disc.	Drug	Grocery	Hard-ware	Home Improv.	Mass Merch.	Memb. Club	Total
Lamps in shelf survey	632,919	651,116	2,378,512	942,699	1,794,480	3,601,828	301,757	10,303,311
Lamps in shelf survey (%)	6%	6%	23%	9%	17%	35%	3%	100%
Lamps purchased in channel (%) based on consumer phone survey	2%	2%	2%	9%	57%	16%	12%	100%

Figure 3 shows that the influence of each market channel varies when comparing lamp availability in the shelf survey (second row) with where lamps are purchased according to the consumer phone survey (third row). For example, if we treated the shelf survey results as a proxy for sales, grocery stores are over-represented since 23% of the lamps available on the shelves are in this channel, but the consumer surveys indicate only 2% of lamps were purchased in this channel. Similarly, 35% of all lamps in the shelf survey were in the mass merchandise channel, but the consumer survey indicates that only 16% of purchases are in that channel. Conversely, the home improvement and membership club channels would be under-represented if we treated shelf survey data as sales, since these channels have lower availability in the shelf survey (17% and 3% for home improvement and membership club, respectively) compared with the consumer survey (57% and 12%).

It was beyond the scope of this research to investigate the source(s) of the discrepancy between the lamps observed in the shelf survey compared with consumer reported preferences. But possible reasons include:

- Product price may create an incentive to purchase these lamps in some channels (e.g., membership club) over others.
- The home improvement channel is characterized by a very wide variety of options, and a certain amount of sales in this channel may reflect that this channel offers a product solution to meet most consumers' needs. In contrast, some of the other channels are limited in the lamp variety on the shelf, and therefore may not offer a viable replacement lamp under some circumstances.

[10] The sell through rate refers to the amount of inventory a retailer receives from a manufacturer or supplier compared to the amount that is sold to the customer, over a given timeframe.

- Home improvement and membership clubs both offer larger packs of multiple lamps, which encourage volume purchasing and reduces the need to purchase through other channels.
- Grocery stores may have a high representation in the shelf survey because there are many grocery stores in the state. Consequently, there are many outlets to potentially purchase these lamps, even though they appear to represent a small portion of lamp purchases.

Regardless of the reason, because of the differences in lamp availability and consumer reported purchasing preferences, TRC developed the multipliers to adjust lamp availability data to better represent lamp sales.

Description of Calculations

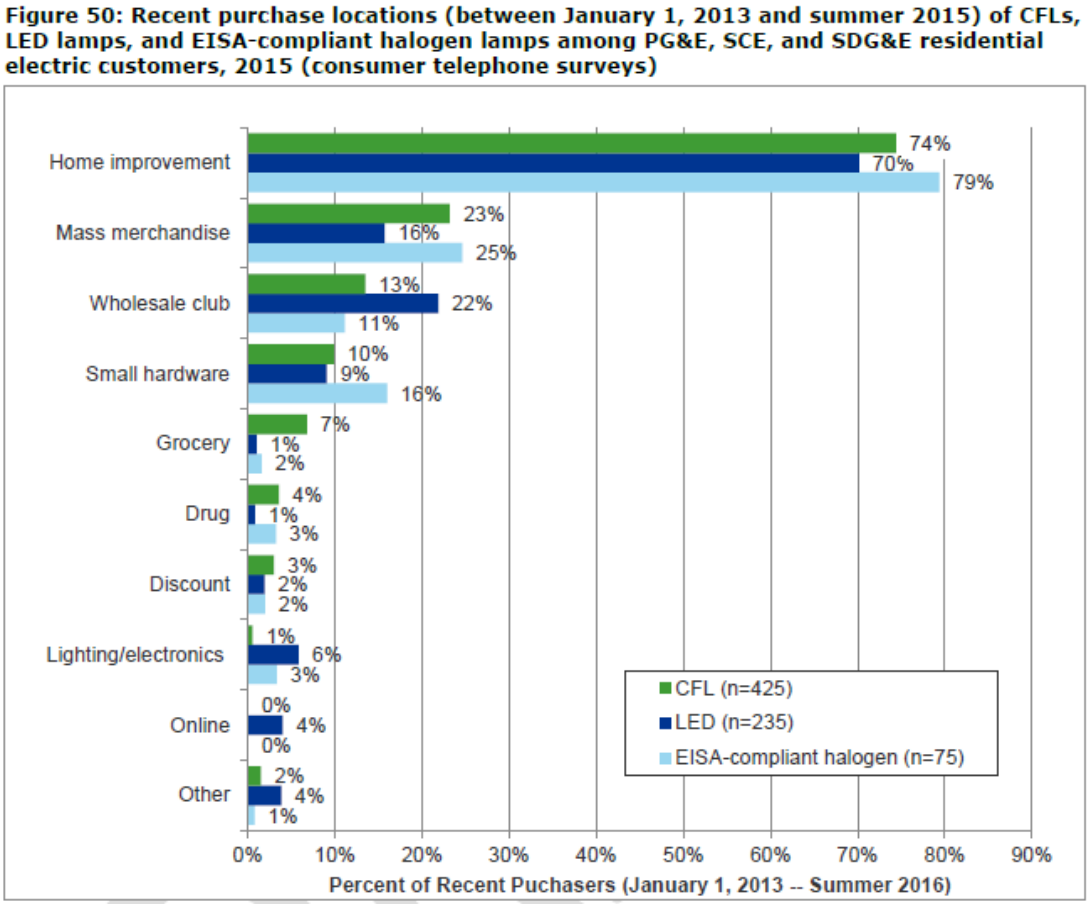
As an overview of our approach, TRC assumed that:

1. Consumers purchased lamps by channel according to the results of the DNV-GL consumer phone survey (DNV-GL 2016a);
2. Within each channel, consumers purchased lamp technologies relative to lamp availability, as found in the winter 2015/16 shelf survey (DNV-GL).

This section provides more description of our methodology.

The consumer survey provides information on purchase locations, by asking consumers in which channels they recently purchased lamps. Multiple channel selections were permitted. Figure 4 provides the survey results. Respondents could provide multiple responses to the question.

Figure 4. Results of Consumer Survey on Channel Preference (DNV-GL 2016a)



This data is recent and is also the most robust survey of consumer preference by channel in California. It provides information from consumers statewide in California, whereas other sources that TRC considered for estimating consumer purchasing preferences were limited to only one IOU territory and had much older information (e.g., collected in 2011).

To develop sales multipliers, TRC first made adjustments to the consumer phone survey (DNV-GL 2016a) results to calculate a "Normalized Preference" for each channel, representing the percent of sales that occur in that channel, and that sum to 100% across all channels. TRC developed the Normalized Preferences percentages, as illustrated in Figure 5 and described here:

- The first set of rows in Figure 5 ("Consumer purchasing preference") show the unadjusted results from the survey. The distribution of values in the consumer survey total to greater than 100%, because respondents were permitted to select more than one channel. Additionally, the consumer surveys included an "Other" category that the shelf survey did not.
- TRC adjusted the consumer survey results by removing the "Other" category, to align the categories with the channels in the shelf survey. Next, TRC normalized results to sum to 100% for each lamp technology. The results of these two steps are shown in the second set of rows in Figure 5: "Removing 'Other" and normalizing to 100%".
- TRC then calculated a weighted average across the four technologies (incandescent, halogen, CFL, and LED) to provide a single percentage for each channel. To weight each technology, TRC used the sales estimates from the LightTracker report (shown in Figure 2 in Section 4.1), and assumed that consumers purchase incandescent lamps according to the channel preferences they identified for halogen lamps. Figure 5 shows the results in the row, "Normalized Preference", which represents the fraction of sales we estimate occurs in each channel.

Figure 5. Consumer Purchasing Preferences (DNV-GL 2016a) and Subsequent Sales Multiplier

Description	Technology or Calculation	Disc.	Drug	Grocery	Hard-ware	Home Improv.	Mass Merch.	Memb. Club	'Other'	Total
Consumer purchasing preference (DNV-GL 2016a)	Halogens	2%	3%	2%	16%	79%	25%	11%	4%	142%
	CFLs	3%	4%	7%	10%	74%	23%	13%	3%	137%
	LEDs	2%	1%	1%	9%	70%	16%	22%	14%	135%
Removing "Other" and normalizing to 100%	Halogens	1%	2%	1%	12%	57%	18%	8%		100%
	CFLs	2%	3%	5%	7%	55%	17%	10%		100%
	LEDs	2%	1%	1%	7%	58%	13%	18%		100%
Normalized Preference (%)	Based on weighted average across technologies	2%	2%	2%	9%	57%	16%	12%	---	100%

4.2.2 Results

TRC used the Normalized Preferences to adjust the shelf survey results for an estimate of lamp sales, as described here and illustrated in Figure 6.

- The first set of rows shows the Lamp Availability per Channel based on the winter 2015/16 shelf survey.
- The second set of rows shows the normalized consumer preference percentages, and the resulting channel sales multipliers. To calculate the multiplier for each channel, TRC divided the "Normalized Preference" (calculated in Figure 5) by the "Lamps in shelf survey". For example, for discount stores, the sales multiplier is 2% / 6% = 0.3.

- The third set of rows provides the estimated lamp sales per channel when applying the sales multipliers to the individual channels and lamp technologies. The final row shows the total sales estimate results per channel.

In Figure 6, TRC rounded the percentages to the nearest whole number and the multipliers to the nearest tenth, so as not to imply a higher level of precision than is appropriate. However, TRC used the full values when calculating the lamp sales numbers. Consequently, there are some discrepancies between the lamp sales numbers and what would be calculated using the rounded (interim) values in Figure 6.

For the multipliers, a value less than one reduces the influence of that channel on the total sales, and a value greater than one increases that channel's influence on sales. For example, for discount stores, the sales multiplier is 2% / 6% = 0.3, so the multiplier reduces this channel's impact on sales.

Figure 6. Calculation of Channel Distribution based on Channel Preference through TRC Sales Multiplier

	Disc.	Drug	Grocery	Hard-ware	Home Improv.	Mass Merch.	Memb. Club	Total	% of Total Lamps
Lamp Availability per Channel based on Winter 2015/16 Shelf Survey									
Incandescent	422,157	58,203	637,796	226,106	168,858	371,491	1,421	1,886,031	18%
Halogen	38,767	272,685	642,739	236,777	445,667	1,419,295	812	3,056,739	30%
CFL	165,242	292,866	891,629	333,854	361,931	1,365,802	140,869	3,552,192	34%
LED	6,753	27,363	206,349	145,963	818,025	445,241	158,655	1,808,349	18%
Total	**632,919**	**651,116**	**2,378,512**	**942,699**	**1,794,480**	**3,601,828**	**301,757**	**10,303,311**	**100%**
Lamps in shelf survey (%)	6%	6%	23%	9%	17%	35%	3%	100%	
Consumer Preference per Channel Information and Sales Multiplier									
Normalized Preference (%) of lamp purchases	2%	2%	2%	9%	57%	16%	12%	100%	
TRC A-lamp Sales Multiplier: Normalized Preference / Lamps in shelf survey	0.3	0.3	0.1	1.0	3.3	0.5	4.0		
Estimated Lamp Sales per Channel based on Consumer Channel Preference									
Incandescent	116,432	17,547	57,652	229,313	552,585	172,867	5,711	1,152,107	11%
Halogen	10,692	82,209	58,099	240,134	1,458,440	660,445	3,262	2,513,281	24%
CFL	45,574	88,293	80,597	338,588	1,184,416	635,553	566,223	2,939,244	29%
LED	1,863	8,249	18,652	148,033	2,676,980	207,185	637,715	3,698,678	36%
Total	**174,561**	**196,299**	**215,001**	**956,068**	**5,872,420**	**1,676,051**	**1,212,911**	**10,303,311**	**100%**

The calculations maintain the total lamp sales observed in the shelf survey (10 million lamps), but shift purchases toward the more heavily favored channels, and away from the less favored channels. For example, the total sales in grocery stores dropped from almost 2.4 million lamps to 215,001 lamps. This is a considerable change, but it now reflects what appears to be a more reasonable sell through rate for products in this channel.

This calculation also changes the percentages of the various lamp technologies that have been sold in the state, because there are different percentages of technologies available in each channel, including different ratios of high efficacy (CFL and LED) versus low efficacy (incandescent and halogen) lamps. Sales in channels with more low efficacy lamps (e.g., grocery) decreased, and sales in channels with more high efficacy lamps (e.g.,

membership club) increased. Consequently, TRC's adjustments result in an *increase* in sales of high efficacy lamps. Figure 6 shows that the distribution of LED lamps has doubled from 18% to 36% through this calculation, and the other light source technologies have decreased to compensate. Incandescent lamps had the largest reduction by percentage, from 18% to 11%.

Another way to interpret TRC's results is as follows: The shelf survey estimated 10 million lamps on California retailer's shelves at the time of the shelf survey. TRC's estimates indicate that, in the time for 10 million lamps to be sold, some of the incandescent lamps observed in the shelf survey were not sold (since the multipliers reduced their sales); while the LEDs observed in the shelf survey were sold, and replaced on retailers' shelves with new LEDs which also sold (since the multipliers doubled LEDs).

Figure 7 reproduces the last column of the final five rows of Figure 6 to show the lamp sales by technology. TRC also calculated the incandescent, halogen, and CFL percentages, after removing LEDs and normalizing to 100% in the last column of Figure 7.

Figure 7. A-Lamp Sales Estimates by Lamp Technology

Lamp Technology	% of Total Sales	% of Total Sales, Removing LEDs
Incandescent	11%	17%
Halogen	24%	38%
CFL	29%	45%
LED	36%	N/A
Total	100%	100%

As shown in Figure 7, after removing LEDs, 45% of A-lamps purchased were CFLs. The remaining 55% of lamp sales (after removing LEDs) were halogen (38%) or incandescent (17%).

4.2.3 Methodology Check

LightTracker provides sales estimates based on Point-of-sales (POS) channels and Non-POS Channels, as described in Section 4.1. Figure 8 summarizes the inclusion of channels in the POS vs Non-POS data in LightTracker.

Figure 8. LightTracker Coverage by Channel

	Discount	Drug	Grocery	Hardware	Home Improve.	Mass Merch.	Membership club
Coverage in LightTracker POS data	Near full	full	full	none	none	full	partial
Assumption of Channel	POS	POS	POS	Non-POS	Non-POS	POS	Non-POS

As a methodology check, TRC totaled our sales estimates in the POS channels (Discount, Drug, Grocery, and Mass Merchandise) and our sales estimates in the Non-POS channels (Hardware, Home Improvement, and Membership Club). TRC then compared our results for POS vs. Non-POS purchases with LightTracker results. As shown in Figure 9, the results were very similar, which indicates that the sales multiplier is a reasonable method to make adjustments to the shelf survey results.

Figure 9. TRC Estimate Compared to LightTracker by Channel Type

Sales Estimate Source	POS: % of total purchases	Non-POS: % of total purchases
LightTracker	24%	76%
TRC estimate	22%	78%

4.3 NEMA Data

TRC obtained the following data on U.S. A-lamp shipments from the NEMA website (cited in Section 3 - References). Figure 10 presents NEMA shipment data by technology, as percentages of all A-lamp shipments, from 2011 through Q3 2016. CFLs are shown in blue. As shown, CFLs comprised approximately 25-30% of A-lamp shipments from 2011 through Q1 2014, and then increased to 47% in Q4 2014. CFL shipments then declined to only 13% by Q3 2016.

Figure 10. NEMA U.S. A-lamp Shipments by Technology

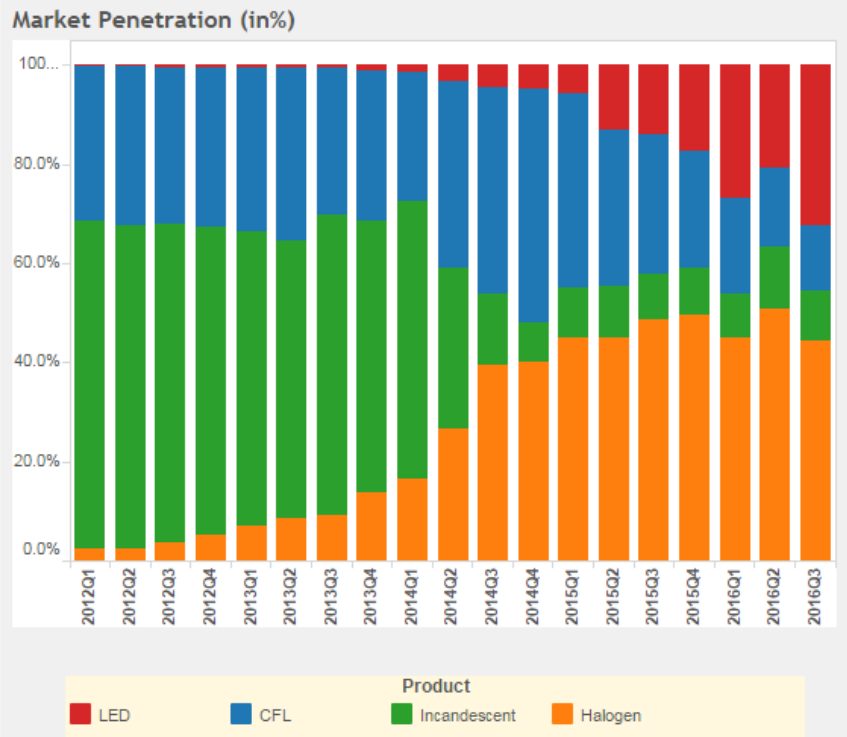


Figure 11 presents the numerical values for specific timeframes to illustrate the following:

- The 2014 Q4 data shows values when CFLs reached its maximum penetration of A-lamp shipments.
- The four quarters of 2015 illustrate the quarter-to-quarter change and the rapidly evolving A-lamp market. As shown, CFL shipments declined significantly during 2015.
- The 2016 Q3 data is the most currently available. As shown in Figure 11, after removing LEDs, the fraction of shipments that are CFLs has dropped by more than half – from 49% in Q4 2014 to 19% in Q3 2016. A similar result is found when LEDs are retained in the analysis: CFL shipments have dropped by more than half – from 47% in Q4 2014 to 13% in Q3 2016.

Figure 11. NEMA U.S. A-Lamp Availability

NEMA data		Raw Data				Removing LEDs		
Year	Quarter	Incan	Halogen	CFL	LED	Incan	Halogen	CFL
2014	Q4	8%	40%	47%	5%	8%	42%	49%
2015	Q1	11%	44%	40%	5%	12%	46%	42%
2015	Q2	11%	44%	32%	13%	13%	51%	37%
2015	Q3	9%	49%	28%	14%	10%	57%	33%
2015	Q4	10%	50%	24%	16%	12%	60%	29%
2015 Average		*10%*	*47%*	*31%*	*12%*	*12%*	*53%*	*35%*
2016	Q1	8%	47%	19%	26%	11%	63%	26%
2016	Q2	13%	51%	16%	21%	16%	64%	20%
2016	Q3	10%	45%	13%	32%	15%	66%	19%
Average of last 4 Quarters (Q4 2015-Q3 2016)		*10%*	*48%*	*18%*	*24%*	*13%*	*63%*	*23%*

For results after removing LEDs, for the most recent four quarters (Q4 2015-Q3 2016), CFLs comprised 23% and the combined result for incandescent (13%) and halogen (63%) lamps is 77%, after rounding.

4.4 California Shelf Survey Data

Figure 12 shows results of the 2015/16 winter shelf survey, weighted by DNV-GL to account for sampling of the retail stores. This figure presents results across all market channels for A-lamps (including twister CFLs)– first for all technologies, and then after removing LEDs. The data is based on almost 350,000 A-lamps observed on California retailers' shelves (based on the unweighted shelf survey results – not shown), representing over 10 million lamps based on the case weights of the sampled lamps.

Figure 12. California 2015/16 Winter Shelf Survey Results (DNV-GL)

Lamp Technology	Discount	Drug Store	Grocery	Hardware	Home Improvement	Mass Merchandise	Membership Club	Overall
CFL	165,242	292,866	891,629	333,854	361,931	1,365,802	140,869	3,552,192
Halogen	38,767	272,685	642,739	236,777	445,667	1,419,295	812	3,056,739
Incand.	422,157	58,203	637,796	226,106	168,858	371,491	1,421	1,886,031
LED	6,753	27,363	206,349	145,963	818,025	445,241	158,655	1,808,349
Total	632,919	651,116	2,378,512	942,699	1,794,480	3,601,828	301,757	10,303,311

Using the "Overall" number of lamps across all channels (the final column in Figure 12), TRC calculated the percent of lamps available by technology, with and without LEDs, as shown in Figure 13. Without LEDs, CFLs comprise 42% of available lamps, and the combined result for incandescent (22%) and halogen (36%) lamps is 58%.

Figure 13. Percent of Lamps Available By Technology in DNV-GL 2015/16 Winter Shelf Survey

	Raw Data (All Technologies)				Removing LEDs		
	Incandesc.	Halogen	CFL	LED	Incandesc.	Halogen	CFL
	1,886,031	3,056,739	3,552,192	1,808,349	N/A		
% of Total A-lamps	18%	30%	34%	18%	22%	36%	42%

Because lamp availability is an indicator of, but not the same as, lamp sales, TRC estimated lamp sales using the 2015/16 winter shelf survey results and data indicating consumers' purchasing preference by channel. Section 4.2 describes the methodology and results.

TRC also analyzed trends in A-lamp availability by technology in the California shelf surveys over time, to inform how lamp installations may have changed since the CLASS and CSS surveys were conducted. As shown in Figure 14, incandescent and CFL availability has steadily decreased, while LED availability has steadily increased. Halogen availability increased significantly from the summer 2012 to the winter 2014/15 survey, but slightly declined from the winter 2014/15 to the winter 2015/16 survey. These results indicate that incandescent and CFL installations have likely decreased since the CLASS and CSS surveys, while halogen and LED installations have likely increased.

Figure 14. A-Lamp Technology Trends in California Retailer Shelf Surveys (DNV-GL)

Lamp Technology	Summer 2012	Summer 2013	Winter 2014/15	Winter 2015/16
Incand.	34%	28%	21%	18%
Halogen	5%	21%	35%	30%
CFL	60%	49%	37%	34%
LED	1%	2%	8%	18%
Total	100%	100%	100%	100%

4.5 Consumer Intercept Survey (DNV-GL 2016a)

As reported in the California Residential Replacement Lamp Market Status Report (DNV-GL 2016a), DNV-GL conducted a consumer intercept survey as part of the winter 2014/15 retailer shelf survey[11]. The survey asked consumers that were purchasing LEDs what lamp technologies they planned to replace with these LEDs. Figure 15 shows results, with the column "All Responses" taken from Figure 58 in the DNV-GL (2016a) report. TRC added the middle column after removing the empty sockets and "Don't Know" responses and normalizing to 100%; and the last column after removing LEDs and normalizing to 100%. After removing LEDs, CFLs comprise 51% of lamp installed, and the combined result for incandescent (44%) and halogen (5%) lamps is 49%.

[11] DNV-GL conducted a similar consumer intercept survey as part of the winter 2015/16 shelf survey, but results were not published at the time of this white paper's development.

Figure 15. A-Lamps to be Replaced with LEDs, (Winter 2014/15 Consumer Intercept Survey)

	A-lamps to be Replaced with LEDs		
Baseline Technology	**All Responses (n=281)**	**Responses, after Removing Empty Sockets and Don't Know**	**Responses, after Removing Empty Sockets, Don't Know, and LEDs**
Incandescent	41%	43%	44%
Halogen	5%	5%	5%
CFL	47%	49%	51%
LED	2%	2%	
Empty Socket	2%		
Don't Know	2%		
Overall	100%[12]	100%	100%

4.6 Consumer Phone Survey (DNV-GL 2017)

As part of the impact evaluation of the 2015 ULP, DNV-GL conducted a phone survey of consumers, which included questions about what lamp types consumers had replaced with recently purchased LEDs. Figure 16 presents the results, taken from the 2015 ULP (Table 27 in DNV-GL 2017). The first column presents results for all technologies. The final column shows results after removing LEDs. After removing LEDs, CFLs comprised 32% of lamp replacements, and the combined result for incandescent (54%) and halogen (15%) lamps totals 68% after rounding.

Figure 16. Lamps Replaced by LEDs (2015 Consumer Telephone Survey)

	A-lamps to be Replaced with LEDs	
Baseline Technology	**All Technologies (n=2,364)**	**Removing LEDs**
Incandescent	51%	54%
Halogen	14%	15%
CFL	30%	32%
LED	5%	
Overall	100%	100%

4.7 CLASS 2012 Results

Figure 17 shows CLASS 2012 (DNV-GL 2014) results, as the percent of total lamps that were A-lamps (including spiral CFLs) by technology. These results are based on an on-site survey of approximately 2,000 homes in California conducted in 2012.

[12] Results have been rounded to the nearest whole number. The figure provides values for incandescent, halogen, and CFL lamps. TRC estimated the percent of LEDs, empty sockets, and "Don't Know" responses from reading Figure 58 in DNV-GL 2016a.

Figure 17. Percent of All Lamps that are A-lamps (by Technology) in CLASS 2012

	CFL A-Type	CFL Spiral	Halogen A-Type	Incand.	LED	Total
% of Total lamps	1%	23%	0.1%	23%	1%	48%

As shown in Figure 17, almost half (48%) of the lamps found in CLASS 2012 were A-lamps. Other lamp types included reflectors, globes, candelabra, linear lamps, and other lamp types.

TRC normalized the values in Figure 17 so that they totaled to 100% to calculate the percent of each technology for A-lamps, as shown in Figure 18. After removing LEDs, CFLs comprised 50% of A-lamps, and the combined result for incandescent (49%) and halogen lamps (0.2%) is 50% after rounding.

Figure 18. Fraction of A-Lamps by Technology in CLASS 2012

	All Lamp Technologies				Removing LEDs		
	Incand.	Halogen	CFL	LED	Incand.	Halogen	CFL
% of Total A-lamps	48%	0.2%	49%	2%	49%	0.2%	50%

TRC notes that the data in CLASS 2012 are approximately five years old. Since DEER 2016 estimates that the EUL for an indoor lamp is 3.5 years for residential buildings, many of the lamps observed in that survey – particularly the incandescent lamps – have likely burned out and been replaced. Lamp market availability data sources (including NEMA data and the California shelf surveys conducted since 2012) indicate that incandescent lamp installations have likely decreased, while halogen and LED installations have likely increased. Based on the California shelf surveys, CFL installations have likely decreased as well, as described in Section 2.

4.8 California Commercial Saturation Survey (CSS)

TRC reviewed lamp saturation data from the CSS (Itron 2014b). The CSS collected data from 1,439 on-site surveys of office, retail, warehouse, colleges, healthcare (non-hospital), restaurants, grocery, schools, hotel/motel, and miscellaneous buildings, surveyed between the first quarter of 2012 and the fourth quarter of 2013. Figure 19 shows the distribution of incandescent, halogen, CFL, and LED lamps as a percentage of all lighting. This table includes both medium screw-based (MSB) and pin-based lamps – e.g., MR-16s and pin-based CFLs. CSS does not separate out MSB versus pin-based lamps in their data for all incandescent, halogen, CFL, and LED lamps. However, many of the CFLs captured in Figure 19 are pin-based lamps. Overall, this table indicates that MSB and pin-based lamps comprise a small fraction of lamps in commercial buildings (16% total).

Figure 19. Incandescent, Halogen, CFL, and LED Lamps as a percent of all Lighting from CSS

	Incandescent	Halogen	CFL	LED	Total
% of all Sources	4%	2%	9%	1%	16%

Figure 20 presents the distribution of MSB lamps for incandescent, CFL, halogen, and LED lamps. For these technologies, the CSS study distinguishes between MSB lamps and pin-base lamps, but does not further differentiate within the MSB category. Thus, data shown in Figure 20 includes all MSB lamps, including A-lamps, reflectors (PAR- and R-lamps), and globes.

In addition, the CSS report did not report lamp distributions for the survey sample as a whole. Instead, results were segmented by building type, business size, or program participation. To determine overall distribution, TRC calculated a weighted average based on program participation values, as shown below in Figure 20. Note that TRC removed pin-based lamps, because these are not included in A-lamps; consequently, each row in Figure 20 totals to less than 100%.

Figure 20. MSB Incandescent, Halogen, CFL, and LED lamp distribution from CSS

	Incand.	Halogen	CFL	LED
EE Lighting Non-Participant (n=900)	22%	6%	34%	3%
EE Lighting Participant (n=300)	13%	6%	31%	8%
EE CFL/LED Participant (n=159)	14%	5%	35%	6%
Weighted Average (TRC Calculated)	**19%**	**6%**	**33%**	**4%**

Based on these values, TRC recalculated the percentages of each technology type after normalizing to 100%, and then after removing LEDs, as shown in Figure 21. After removing LEDs, CFLs comprise 57%, and the combined result for incandescent (33%) and halogen (10%) lamps totals 43%.

Figure 21. Percent of MSB Incandescent, Halogen, and CFL lamps from CSS

	All Results				After Removing LEDs		
	Incand.	Halogen	CFL	LED	Incand.	Halogen	CFL
% of Total	30%	9%	53%	7%	33%	10%	57%

5. APPENDIX B – LIGHTTRACKER METHODOLOGY

Apex Analytics provided the following description of their methodology for developing the LightTracker sales report.

To: TRC Energy Services

From: Scott Dimetrosky, Apex Analytics

Date: April 17, 2017

Re: LightTracker Sales Report Methodology

Data Sources

To develop the LightTracker sales report, Apex Analytics leveraged a variety of data sources for model development, but relied primarily on 2015 sales data prepared by the Consortium for Retail Energy Efficiency Data (CREED) LightTracker initiative.[1,2] These sales data were primarily generated from two sources: point-of-sale (POS) state sales data (representing one group of retail channels) and National Consumer Panel (NCP) state sales data (representing a different group of retail channels). These two sources collectively represent the majority of bulb sales across the United States.

The primary model input data sources are listed here:

- National bulb sales
  - POS data (grocery, drug, dollar, discount, mass merchandiser, and selected club stores)
  - Panel data (home improvement, hardware, online, and selected club stores)

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1 CREED serves as a consortium of program administrators, retailers, and manufacturers working together to collect the necessary data to better plan and evaluate energy efficiency programs. LightTracker is CREED's first initiative, focused on acquiring full-category lighting data—including incandescent, halogen, CFL, and LED bulb types—for all distribution channels in the entire United States. As a consortium, CREED speaks as one voice for program administrators nationwide as they request, collect, and report on the sales data needed by the energy efficiency community. There are more details available online: https://www.creedlighttracker.com. Note that 2015 data was the most recent year available at the time of this study.

2 The information contained herein is based in part on data reported by IRI through its Advantage service, interpreted solely by LightTracker. Any opinions expressed herein reflect the judgement of LightTracker, Inc. and are subject to change. IRI disclaims liability of any kind arising from the use of this information.

- U.S. Census Bureau import data (CFLs)
- ENERGY STAR® shipment data (imports and ENERGY STAR market share)
- North American Electrical Manufacturers Association shipment data

Lighting Sales

The LightTracker POS dataset includes lighting sales data for grocery, drug, dollar, club, and mass market distribution channels. These data represent actual sales that are scanned at the cash register for participating retailers.

The NCP represents a panel of approximately 100,000 residential households that are provided a handheld scanner for their home and instructed to scan every purchase they make that has a bar code. For California, the NCP included approximately 6,000 households in 2015. The use of a scanner avoids the potential recall bias that is prevalent in self-report methods that ask about lighting purchases. While these data included scans from both the channels in the POS data and the remaining channels, only scans from the remaining channels (home improvement, hardware, online, and selected club stores) are included so as to avoid double counting the POS sales.

Though the dataset Apex Analytics received included detailed records of lighting data purchases, the data required a considerable effort to ensure data integrity and the inclusion of all necessary bulb attributes. For example, not all records had some of the more critical variables populated, including bulb type, style, and wattage, and some clearly had erroneous values (e.g., 60-watt CFLs).

After a thorough review and quality control of the dataset, Apex Analytics reclassified, standardized, populated missing records, created additional variables, and performed general enhancements to the data. To populate missing records, validate existing records, and include additional bulb attributes, Apex Analytics created a proprietary Universal Product Code (UPC) database with approximately 20,000 bulbs from four sources:

- Manufacturer product databases provided to LightTracker
- Product catalogs downloaded from manufacturer websites
- Product offerings downloaded from retailer websites
- Automated lookups of online UPC databases, such as www.upcitemdb.com

LightTracker then merged the UPC bulb database with the POS/panel data, populating fields based on a hierarchy of data sources based on reliability, prioritized in the following order: manufacturer specifications, UPC lookups, and original IRI-based database values. Apex Analytics also conducted a large number of manual website lookups of individual bulbs to determine final assignments.

In addition, Apex Analytics investigated the bulb assignment and the quantity of bulbs per package by examining the average price per unit and identifying outliers. This process helped us identify misclassification of certain bulb types (e.g., bulbs that were flagged as low cost LEDs but were really LED nightlights, so needed to be classified as "other"), as well as bulb counts that sometimes represented box shipments (e.g., a box identified as having 36 bulbs was really six packages of six-pack CFLs).

The final model ended up representing 39 states, excluding some smaller states that lacked sufficient sample size from the panel data. The model provides sales estimates at the individual state level (for states represented), and aggregated across the U.S. Key aspects of the lighting dataset include:

- 2015 sales volume and pricing for CFLs, LEDs, halogens, and incandescent bulbs for all retailer sectors combined, and broken out by POS and non-POS channels
- Data reporting by state and bulb type
- Inclusion of all bulb styles and controls