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Residential Lighting Forecasting Analysis

Final White Paper

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Prepared for Pacific Gas and Electric Company

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I. INTRODUCTION

At the request of Pacific Gas and Electric Company (PG&E), TRC Energy Services (TRC) estimated past residential electricity lighting use (from 2012 to 2016) and forecasted residential electricity lighting use in the near future (from 2017 to 2018) under different scenarios of lighting technology penetrations.

The purpose of this analysis is to:

- Provide the range of possible residential lighting electricity use to inform PG&E forecasting.
- Estimate progress towards the California Assembly Bill (AB) 1109 goal to reduce residential electricity use by 50% from 2007 to 2018[1], and identify reductions needed to meet this goal.
- Illustrate the effect of different penetrations of high efficacy technology (CFL and LED) versus low efficacy technology (incandescent and halogen) purchases on residential lighting electricity use.

PG&E lighting programs, including upstream rebates for high efficacy lamps, can influence lamp purchases, so this analysis illustrates the potential effect of different levels of lamp rebates towards meeting the AB 1109 goals, and towards influencing the penetration of high efficacy lamps.

[1] From http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1109_cfa_20070604_201220_asm_floor.html Although the AB 1109 goal is for indoor electricity use only, TRC conducted its analysis for all residential lighting electricity use, because many data sources (such as lamp availability data) are not available for indoor lighting only. Because indoor lighting comprises the majority of residential lighting electricity use (DNV-GL 2014a), results for total residential lighting electricity should reflect indoor results.

2. Executive Summary

This analysis finds that California has made significant progress towards meeting its AB 1109 goals. TRC estimates that from 2007 to 2016, residential lighting electricity use declined by 33%, or an average reduction of 4% per year. While this is an impressive achievement, residential lighting electricity use must decline an additional 17% in the next two years (an average of 8.5% annually) to meet the AB 1109 goal of reducing residential lighting electricity use by 50% by 2018.

TRC developed five scenarios, which all represent possible residential lighting electricity use for 2017 to 2018. Figure 1 summarizes each scenario, and the resulting residential lighting electricity use under each scenario. Note that:

- TRC estimates that LEDs comprised 33% of all lamp sales in 2016, so LED adoption increases under all scenarios. The scenarios differ in the degree to which adoption increases, and (for Scenario 5) by the early retirement rate.
- TRC estimates that for 2016, average household residential lighting electricity use was 1,050 kWh, and California residential lighting electricity use was 13,666 GWh. Consequently, household and statewide lighting electricity decline under all scenarios, as households replace incandescent lamps with more efficient technologies. However, the scenarios differ in the degree of that decline.

Figure 1. Summary of Scenarios and Forecasted Residential Lighting Electricity Use

Scenario	Description	LEDs (% of Total Sales) in 2018	Household Lighting Elec. Use, 2018 (kWh)	CA Res. Lighting Elec. Use, 2018 (GWh)	CA Res. Lighting Elec. Use Decline: 2007-2018 (%)
1. Average Trajectory	Based on trajectories from Summer 2013 to winter 2015/16 shelf surveys[2] (over past 2.5 years)	53%	906	12,008	45%
2. Most Recent Trajectory	Based on trajectories from winter 2014/15 to winter 2015/16 shelf surveys (over past 1 year)	61%	883	11,702	47%
3. Accelerating Trajectory	Reductions needed to meet, but not exceed, the AB 1109 goal. Would require accelerating trajectories (i.e., a faster increase in LED sales) than Scenarios 1 and 2	72%	852	11,296	50%
4. Best for Replacements	Assumes lamp replacements are 100% high efficacy by 2018	85%	806	10,685	54%

[2] The DNV-GL California shelf surveys capture the number of lamps available for purchase on retailers' shelves over a given timeframe – typically over a two to three month period. DNV-GL periodically conducts these shelf surveys as part of impact evaluations of the Investor Owned Utilities' residential upstream lighting programs. The results reflect a "snapshot in time" of lamp availability.

Scenario	Description	LEDs (% of Total Sales) in 2018	Household Lighting Elec. Use, 2018 (kWh)	CA Res. Lighting Elec. Use, 2018 (GWh)	CA Res. Lighting Elec. Use Decline: 2007-2018 (%)
5. Best for Replacements + High Early Retirement	Assumes lamp replacements are 100% high efficacy by 2018, and 25% of all incandescents, halogens, and CFLs are retired early and replaced with LEDs	85%	668	8,861	68%

As shown in Figure 1, California would fall slightly short of the AB 1109 goal of reducing residential lighting electricity by 50% under Scenarios 1 and 2, which are based on recent trajectories. In addition, Scenarios 1 and 2 assume that all general service lamp (GSL) sales would be high efficacy by the second half of 2018, due to Title 20 appliance standard requirements for GSLs manufactured on or after January 1, 2018. The goal would be just met under Scenario 3, which requires an acceleration in the adoption rate of LEDs. Under Scenarios 4 and 5, the goal would be exceeded, but would require a much greater increase in the adoption rate of LEDs. Scenario 5 also calls for higher early retirement than past California household trends.

Other findings from this analysis include the following:

- New efficacy requirements will affect all GSLs manufactured on or after January 1, 2018 under Title 20 in California, through early adoption of Energy Independence and Security Act (EISA) Phase 2 requirements. Halogen lamps will not be able to meet the efficacy requirements, leaving CFLs and LEDs as the only GSL options. Because of the lag time for manufacturing requirements to affect consumer purchases, the forecasts in this analysis assume that all GSLs would comply with Title 20 in the second half of 2018 (based on data showing how quickly incandescent lamp shipments complied with EISA Phase 1 requirements). However, non-GSLs comprised slightly less than half (45%) of lamps available in the winter 2015/16 shelf survey, indicating that there will still be a large portion of lamps unregulated by Title 20. Section 4.2 provides more detail on upcoming regulations, including Title 20.
- The fraction of lamps that PG&E customers have purchased that were rebated has declined significantly – from approximately half in 2008, when PG&E provided a large number of CFL rebates – to less than one-tenth in 2015, as PG&E has scaled back its Upstream Lighting Program (ULP) and focused its rebates on LEDs. This decrease in market intervention limits the ability of the ULP to move the market towards the more optimistic (greater lighting electricity reduction) scenarios. Section 4.3 provides current and past rebated lamp penetrations.
- TRC's estimate of the residential lighting electricity use for 2012 is approximately the same as DNV-GL's estimate for 2009 in the Residential Appliance Saturation Study (RASS: DNV-GL 2010). Both estimates are approximately 1,400 kWh/year for the average California household. Section 7.2 discusses this similarity.

Overall, this analysis found that the residential lighting electricity use has declined significantly, but that California may fall slightly short of meeting its AB 1109 goals. While upcoming requirements – particularly Title 20 for GSLs – will push the market towards greater uptake of high efficacy lamps, utility incentives can still play a role, particularly for non-GSLs after 2018. In addition, utility codes and standards programs can continue to support federal or state standards that increase energy efficiency requirements of residential lighting products.

The results of this analysis should be treated as high-level estimates, and Appendix A (Section 7) describes the limitations of this white paper.

3. METHODOLOGY

This section provides an overview of our method for calculating past residential lighting electricity use, the scenarios for future electricity use, and the calculation of the rebated sales fraction. As described in Appendix A (Section 7), this analysis used various assumptions, so the results are high-level estimates. Appendix B (Section 8) provides detailed methodology.

3.1 Estimate of Past Residential Lighting Electricity Use

TRC began by estimating past residential lighting electricity use changes – i.e., from 2007 to 2016. Our analysis leveraged results from the California Lighting Technology Center study, “Lighting Electricity Use in California”, (CLTC 2014) that estimated residential lighting electricity use declined from 2007 to 2010. The CLTC study found a 7% reduction in residential lighting electricity use from 2007 to 2010.

TRC then estimated lighting electricity use from 2012 to 2016 by using the average household lamp inventory from an in-home survey conducted in 2012 (DNV-GL 2014a: California Lighting and Appliance Saturation Survey [CLASS] 2012) and projecting it forward to 2016 by assuming that lamps would be:

- Removed, primarily because of burn out according to the effective useful life (EUL) of each technology. TRC also assumed a small rate of early retirement, so that the total number of lamp purchases in our model for 2015 equaled LightTracker sales estimates[3] for 2015[4].
- Replaced based on TRC’s estimate of lamp sales[5].

For all years, TRC assumed that the average hours of use (HOU) for lamps equaled the California average found in a 2008 metering study in California homes (Gaffney et al., 2010): 1.9 hours per day.

For the 2010 to 2012 timeframe, TRC interpolated the decline per year in residential lighting electricity use from the CLTC (2014) study and the TRC lamp replacement model.

While the AB 1109 goal was specifically for indoor residential electricity use, TRC did not have channel preference data or availability data specific to indoor lighting only. Consequently, TRC estimated trends for all residential lighting (indoor and outdoor), and assumed that the indoor lighting findings would follow these trends. Note that these estimates include population growth (approximately 0.9% additional households per year based on census data, described in section 8.3), because the AB 1109 goal was for reductions in statewide residential lighting electricity use, not reductions on a per household basis.

Figure 2 provides results of estimating residential lighting electricity use reduction from 2007 to 2016.

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[3] The LightTracker report (Apex Analytics, 2016) is an estimate of lamp sales. To develop the LightTracker report, Apex Analytics uses actual point-of-sales (POS) data from some channels. For the remaining (non-POS) channels, Apex Analytics extrapolates purchases from a sample of consumers that scan their purchases.

[4] In our lamp replacement model for 2012 through 2016, TRC calculated a total early retirement rate of 6%, averaged across technologies, so that total lamp purchases in our model for 2015 would equal the number of lamps based on sales estimates for California: 9 per household for 2015 based on the LightTracker report (Apex Analytics 2016) and the number of CA households from the U.S. census. TRC then assumed different early retirement rates for technologies (1-7%, as described in section 8.2) so that the early retirement weighted average was 6%.

[5] TRC developed a method for estimating lamp sales based on results of California retailer shelf surveys (DNV-GL, ongoing) which show lamp availability for each market channel, and applying sales multipliers based on consumers’ preferences for purchasing lamps in each market channel (based on results of a telephone survey – DNV-GL 2016). Section 8.4 describes TRC’s lamp sales methodology.

Figure 2. Estimate of Residential Lighting Electricity Use Reduction: 2007 - 2016

Timeframe	Res. Lighting Elec. Use (% Reduction)	Decline / Year	Source
2007-2010	7.0%	2.3%	CLTC 2014
2010-2012	7.1%	3.5%	Averaging "Decline / yr" of CLTC 2014 and TRC lamp replacement model
2012-2016	19.0%	4.7%	TRC lamp replacement model
Total: 2007-2016	**33%**	**4%**	**Combining above results**

Overall, TRC's analysis indicates that residential lighting electricity use declined 33% from 2007 to 2016, an average of 4% decline annually. While this is impressive progress, another 17% of reductions is needed (an average of 8.5% annually) in the next two years (2017 - 2018) to meet the AB 1109 goal.

For 2016 – the starting point for all scenarios – TRC estimated that average household lighting electricity use was 1,050 kWh and statewide residential lighting electricity use was 13,666 GWh.

3.2 Future Residential Lighting Electricity Use Scenarios

3.2.1 Description of Scenarios

To forecast residential lighting electricity use and to investigate whether achieving the AB 1109 goal is possible, TRC developed five scenarios for residential lighting electricity use for 2017 to 2018. Figure 3 describes each scenario. Because recent trends indicate that the main change will be an increase in LED sales, Figure 3 also provides the forecasted penetration of LEDs under each scenario.

- **All scenarios assume an increase in LED sales.** TRC estimates that approximately 33% of lamp sales were LEDs in 2016 (as shown in Figure 4 below). As shown in Figure 3, the scenarios assume LED penetration rates for 2018 that vary between 53% and 100%. Thus, all scenarios assume an increase in LED sales compared with 2016, but differ in the extent to which that increase will occur.
- **Scenarios 1 through 4 assume early retirement rates to align with past lamp sales estimates** (1% to 7%, depending on technology). Scenarios 1 through 4 assume the same early retirement rates as our 2013-2016 lamp replacement model, described in Section 8.2.
- **Scenario 5 assumes high early retirement** (25% for incandescent, halogen, and CFL lamps; and 1% for LEDs), and therefore an increase in total lamp purchases compared with past trends.

Figure 3. Summary of Scenarios for Residential Lighting, 2017 - 2018

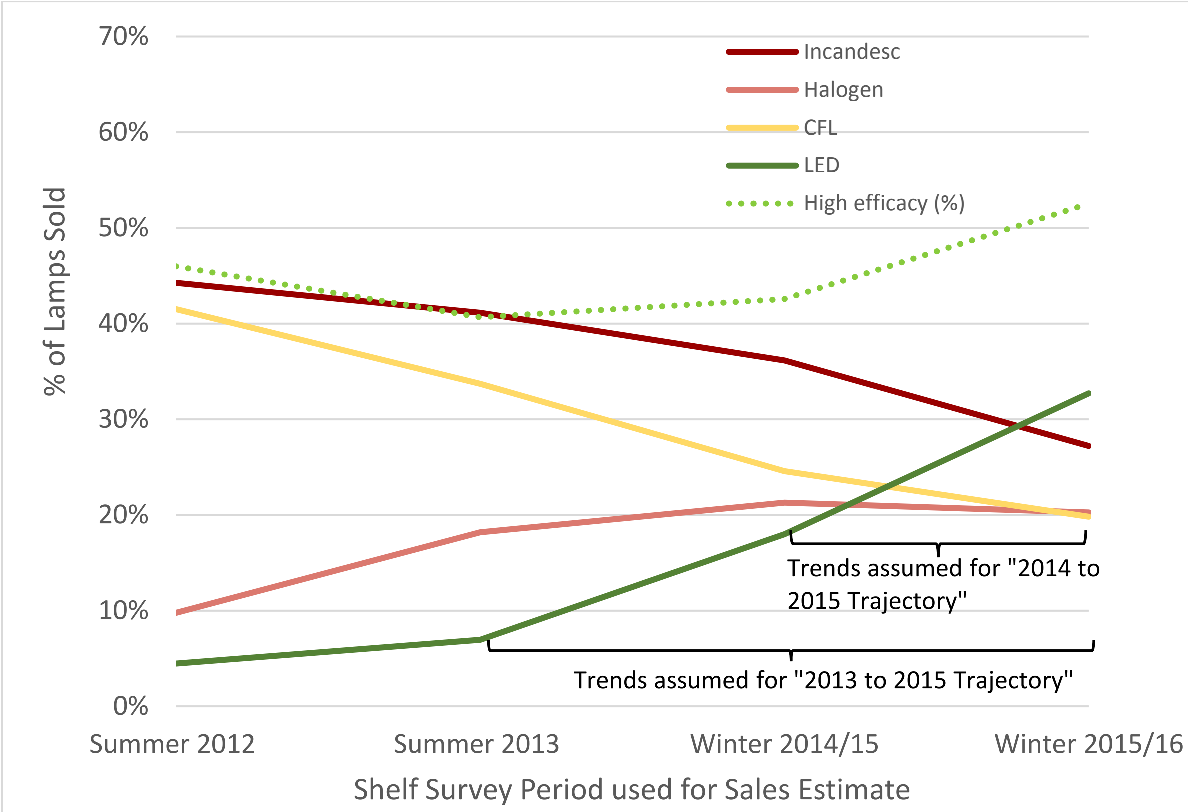
Scenario	Description	LEDs (% of Total Sales) in 2018
1. Average Trajectory	Based on trajectories from summer 2013 to winter 2015/16 shelf surveys (over past 2.5 years)	53%
2. Most Recent Trajectory	Based on trajectories from the winter 2014/15 to winter 2015/16 shelf surveys (over past 1 year)	61%
3. Accelerating Trajectory	Reductions needed to just meet (but not exceed) the AB 1109 goal. Would require accelerating trajectories (i.e., a faster increase in LED sales) than Scenarios 1 and 2	72%
4. Best for Replacements	Assumes lamp replacements are 100% high efficacy by 2018.	85%
5. Best for Replacements + High Early Retirement	Assumes lamp replacements are 100% high efficacy by 2018, and 25% of all incandescent, halogen, and CFL lamps are retired early and replaced with LEDs.	85%

3.2.2 Rationale for Scenarios

This section describes the rationale for each of the five scenarios of future residential lighting electricity use. All scenarios are intended to represent possible outcomes for lamp sales, early retirement rates, and resulting electricity use.

TRC used past trajectories to develop Scenarios 1 and 2. Figure 4 shows TRC's sales estimates based on California shelf surveys conducted in summer 2012, summer 2013, winter 2014/15, and winter 2015/16.

Figure 4. Sales Estimates and Trajectories Based on California Shelf Surveys



In addition, TRC forecast changes in the lighting market due to Title 20-2015, which will require that all GSLs manufactured on or after January 1, 2018, meet an efficacy requirement of at least 45 lumens per watt. Based on analysis of lamp availability in the winter 2015/16 shelf survey, TRC found that 55% are GSLs that must meet this new Title 20 efficacy requirement.[6] The remaining 45% are exempt because they are not medium-screw based (primarily candelabra-based), not GSL type (primarily reflectors), or outside the regulated lumen range (i.e., < 310 or > 2600 lumens). Because some lamps are exempt for more than one reason (e.g., candelabra-based and < 310 lumens), TRC removed the overlap in exemptions to calculate that 45% of total lamps would be exempt. Figure 5 shows the percent of lamps in the winter 2015/16 shelf survey that would be exempt from the upcoming Title 20 requirements.

[6] Small-diameter directional lamps, including pin-based reflectors such as MR 16 lamps, must also meet new efficacy requirements. Pin-based reflectors comprised 0.3% of lamps available in the winter 2015/16 shelf survey, and TRC included these lamps in estimating that 55% of lamps must meet the new Title 20 efficacy requirements.

Figure 5. Lamps Exempt from Upcoming Title 20 Requirements

Lamp category		Lamps	Lamps (% of Total)
Total lamps in winter 15/16 shelf survey		17,759,649	100%
Exempt from Title 20	Not medium screw-based (mostly candelabras)	3,056,954	17%
	Exempted types (mostly reflectors)	2,752,340	15%
	Unregulated lumen bins (< 310, > 2600)	2,617,551	15%
	Total exempt – including overlap	8,426,845	47%
	Total exempt – removing overlap	**8,025,890**	**45%**

For Scenarios 1 and 2, TRC assumed that all lamps would follow past trajectories for 2017 and for the first half of 2018. For the second half of 2018, TRC assumed that all non-GSLs would follow past trajectories, and that all GSLs would be high efficacy to meet the requirements of Title 20. TRC's assumption for GSL compliance is based on how quickly incandescent lamp shipments declined at the national level under EISA Phase 1 requirements. Although EISA Phase 1 took effect on different dates for different lamp classes, the largest regulated class was 60-Watt equivalent lamps, for which EISA Phase 1 effectively prohibited manufacturing of incandescent lamps at the national level beginning January 1, 2014.[7] As shown in Figure 8 (in Section 4.1) Scenario Analysis Results, National Electrical Manufacturers Association (NEMA) quarterly data shows that incandescent lamp shipments continued at pre-EISA levels in 2014 Q1 (56%), began to decline in 2014 Q2 (32%) and Q3 (13%) shipments, and reached their current levels (compliant with EISA Phase 1) by 2014 Q4 (8%)[8]. To forecast Title 20 compliance, TRC split 2018 into halves (rather than quarters) for simplicity, and assumed that the new Title 20 requirements will not affect GSLs the first half of 2018 purchases, and that all GSLs will comply with Title 20 in the second half of 2018. This assumption may slightly overestimate the speed at which Title 20 affects residential lighting, since our assumption is based on lamp shipment compliance, and there will be a lag between shipments and household lamp installations (to allow for shipment distribution, stocking, and purchases).

By combining analysis based on past trajectories with a forecast for the effect of Title 20, TRC developed Scenarios 1 and 2 as follows:

- **Scenario 1** assumes that the trajectories from the summer 2013 to winter 2015/16 shelf surveys (i.e., the rates of incandescent and CFL decline, and slight increase of halogens, between these surveys) will continue for all lamps through 2017 and the first half of 2018, and for non-GSLs for the second half of 2018. For GSLs, for the second half of 2018, Scenario 1 assumes that sales will be 24% CFLs and 76% will be LEDs, based on the rate of CFL decline from the summer 2013 to winter 2015/16 shelf survey.

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[7] EISA Phase 1 is technologically agnostic (i.e., did not prohibit specific lamp technologies), but it required efficacy standards which incandescent technologies could not meet. http://www.lightingfacts.com/Library/Content/EISA

[8] NEMA data include all A-lamp shipments, including classes not regulated by EISA (<310 lumens and > 2600 lumens). There may also be some noncompliance with EISA. Consequently, incandescent lamp shipments have remained at 8-10% since EISA Phase 1 took effect.

- **Scenario 2** assumes that the trajectories from the winter 2014/15 and winter 2015/16 shelf surveys (i.e., the rates of incandescent, halogen, and CFL decline between these surveys) will continue for all lamps through 2017 and the first half of 2018; and for non-GSLs for the second half of 2018. For GSLs, for the second half of 2018, Scenario 2 assumes that sales will be 19% CFLs and 81% will be LEDs, based on the rate of CFL decline from the winter 2014/15 to winter 2015/16 shelf survey.
- For both scenarios, LEDs increase at a rate so that the sum of technologies is 100% for each year. In other words, TRC subtracted the percentages of incandescent, halogen, and CFLs from 100% and assigned the remaining percentage to LEDs. This approach allowed us to forecast an increase in the rate of LED adoption – i.e., to estimate how the slope for LED penetration would change.

Either scenario seems plausible. Given the rapidly changing lighting market, Scenario 2 may be more reliable because TRC developed it based on the most recent data.

Scenario 3 explores how lighting installations would need to shift in order to meet (but not exceed) the AB 1109 goal to reduce residential electricity lighting use by 50% by 2018. Because neither Scenario 2 nor Scenario 1 would meet the goal, the trends in Scenario 3 assume that LED adoption needs to accelerate compared to recent trajectories. Under Scenario 3, the fraction of lamps sold that are LED need to more than double over two years – i.e., increase from 33% in 2016 to 72% in 2018.

Scenario 4 explores a best case scenario for replacement lamps, by assuming that households replace all lamps that burn out (and the approximately 6% of lamps that households retire early) with high efficacy lamps (13% CFLs, 87% LEDs) by 2018. This would require LED sales to almost triple from 2016 (33%) to 2018 (87%).

Scenario 5 explores a best case scenario for replacement lamps along with aggressive early retirement. Scenarios 1 through 4 assume the same early retirement rates as we assumed for 2012 to 2016: 1 to 7% depending on technology. Scenario 5 assumes 25% early retirement for incandescent, halogen, and CFL lamps – i.e., households will replace one-quarter of installed lamps before burn-out and replace these lamps with LEDs. Under this assumption, 60% of LED installations occur because of early retirement, while the remaining LEDs installed (40%) replace burned out lamps. The early retirement assumption in Scenario 5 is supported by a survey of residential customers conducted by DNV-GL (2017). According to the survey, approximately two-thirds (68%) of LED installations replaced working lamps[9]. Under Scenario 5, the total number of all lamps that residential customers purchase (14.1 in 2017 and 11.9 in 2018[10]) would significantly increase compared with past sales estimates of all lamps (8.3 in 2016), as shown in Figure 6.

Figure 6 presents lamp purchase assumptions under each scenario. As shown, Scenarios 3, 4, and 5 assume that LED sales will more than double (as a percent of total lamp purchases) in the next two years. Scenario 5 also assumes that total lamp purchases increase compared to 2016 due to aggressive early retirement.

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[9] DNV-GL 2017, p. 117.

[10] Lamp purchases decrease in Scenario 5 from 2017 to 2018 because TRC assumed 1% early retirement for LEDs, compared with 25% for incandescent, halogen, and CFL lamps. LED socket saturation increases in 2017, so there are fewer lamps to replace with LEDs in 2017.

Figure 6. Lamp Purchase Assumptions under each Scenario

Scenario	Technology	Lamp Purchases		
		2016	2017	2018
1. Average Trajectory	Incandescent	27%	24%	15%
	Halogen	20%	21%	16%
	CFL	20%	17%	17%
	LED	33%	39%	53%
	Lamps purchased	8.3	7.6	7.0
2. Most Recent Trajectory	Incandescent	27%	20%	11%
	Halogen	20%	19%	13%
	CFL	20%	16%	15%
	LED	33%	44%	61%
	Lamps purchased	8.3	7.6	7.0
3. Accelerating Trajectory	Incandescent	27%	14%	7%
	Halogen	20%	16%	13%
	CFL	20%	12%	7%
	LED	33%	58%	72%
	Lamps purchased	8.3	7.6	6.8
4. Best for Replacements	Incandescent	27%	14%	0%
	Halogen	20%	10%	0%
	CFL	20%	16%	15%
	LED	33%	60%	85%
	Lamps purchased	8.3	7.6	6.7
5. Best for Replacements + High Early Retirement	Incandescent	27%	14%	0%
	Halogen	20%	10%	0%
	CFL	20%	16%	15%
	LED	33%	60%	85%
	Lamps purchased	8.3	14.1	11.9

3.3 Calculation of PG&E Rebated Sales Fraction

Because lamp rebates can affect market adoption trends, TRC estimated the fraction of lamps purchased by residential customers that were rebated by PG&E for select years (2008, 2012, and 2015). Note that, although TRC developed the residential lighting electricity use and forecasting scenarios at the statewide level (across all utility territories), TRC only calculated the rebated sales fraction for PG&E, because TRC had some calculation inputs readily available only for PG&E.

TRC developed these estimates using the following calculation:

Rebated Sales Fraction = (Number of PG&E-rebated CFLs and LEDs) / Total Sales in PG&E territory

For the calculation inputs, TRC:

- Identified the number of CFLs and LEDs rebated by PG&E from impact evaluations of the ULP: (DNV-GL 2010 for 2008 rebates, DNV-GL 2014b for 2012 rebates, and DNV-GL 2017 for 2015 rebates). Following the assumption in these evaluations, TRC multiplied the number of rebates by 93% to represent the portion of rebated lamps purchased by PG&E residential customers.[11]

- Estimated the total lamp sales in PG&E territory based on results of our lamp replacement model.
  - As part of the forecasting analysis, TRC estimated total lamps purchased for the average California household in 2012 through 2016. TRC used that model to estimate that the average California household purchased 9 lamps in 2015 (which aligns with results based on LightTracker sales estimates for 2015), and 10 lamps in 2013.
  - While TRC did not develop the lamp replacement model for years prior to 2012, we used the lamp purchases in 2013 (10 lamps), and extrapolated this estimate backwards to prior years (2008 and 2012) based on sales trends. As described in Section 8.2, the number of lamps purchased decreases slightly each year as households replace incandescent lamps (with short lifetimes) with longer lasting technologies. We assumed that lamp sales decreased 3% each year from 2008 to 2012 as households replaced some incandescent lamps with CFLs. Based on these assumptions, TRC estimated 12 lamps purchased per household in 2008 and 11 lamps in 2012.
  - TRC multiplied the number of lamps per household by the number of households in PG&E territory: approximately 4.7 million[12] – to estimate total lamp purchases in PG&E territory.

[11] The evaluations assume that commercial customers purchase the remaining 7% of lamps.

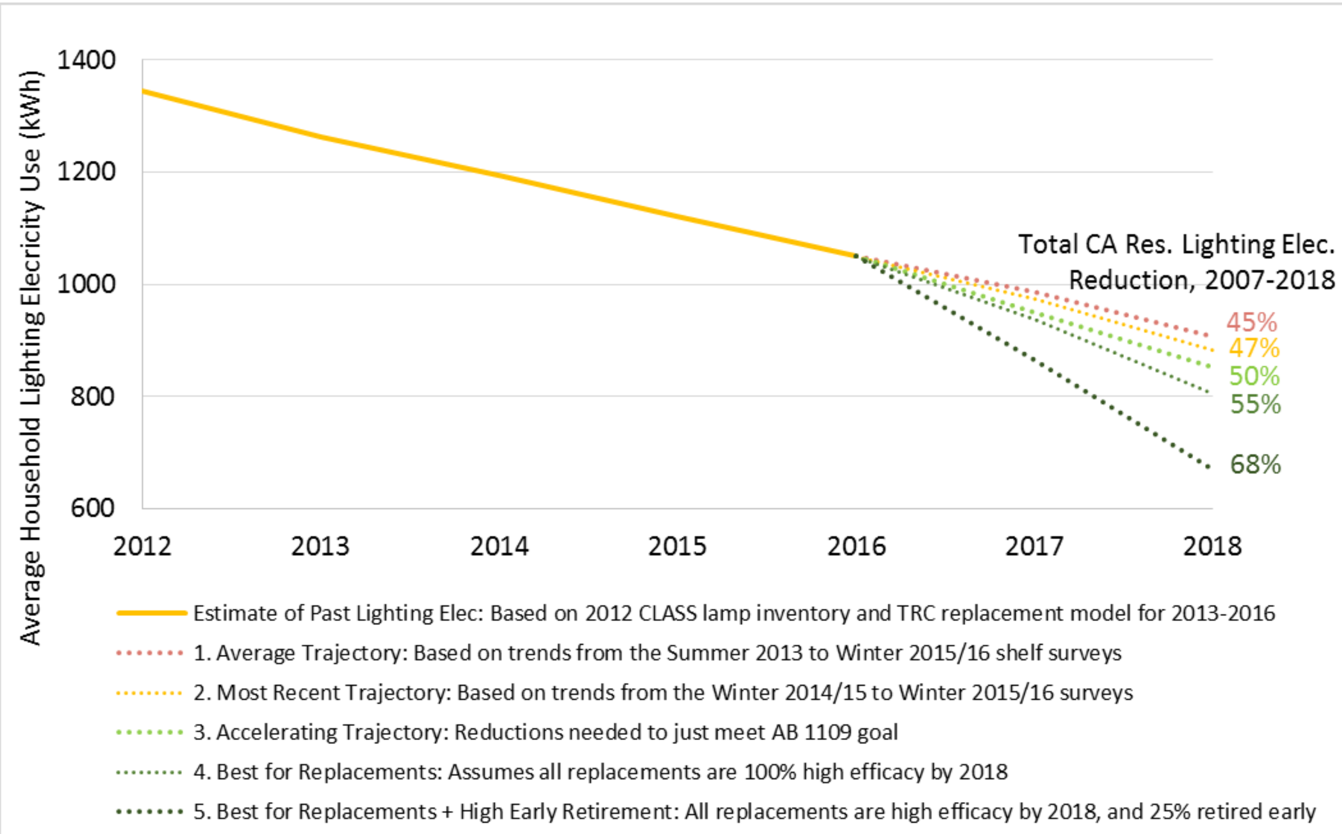
[12] PG&E staff provided the number of residential customers. This value represents the number of dual fuel and electricity-only customers for Q4 2013.

4. Findings

4.1 Scenario Analysis Results

Figure 7 presents residential electricity use results under each scenario. This figure shows our estimate of lighting electricity use from 2012 to 2016 as the solid yellow line and the estimate of lighting electricity use under each scenario for 2017 to 2018 as dotted lines. Figure 2 also shows the resulting reduction in statewide residential lighting electricity use from 2007 to 2018 under each scenario in the right-hand column, for comparison with the AB 1109 goal for a 50% reduction from 2007 to 2018. The horizontal axis begins at 2012 because this is the first year of TRC's analysis. The right-hand column shows statewide reductions from 2007 to 2018, by combining statewide findings from CLTC (2014) and the TRC analysis.

Figure 7. Scenarios for Future Residential Lighting Electricity Use



In all scenarios, residential lighting electricity use will decline as incandescent lamps burn out and households replace them with lamp technologies that are all more efficient. This finding highlights the effect of recent legislation banning the manufacture and importation of traditional incandescent lamps (under the Energy Independence and Security Act [EISA] Phase 1, implemented one year earlier in CA under AB 1109).

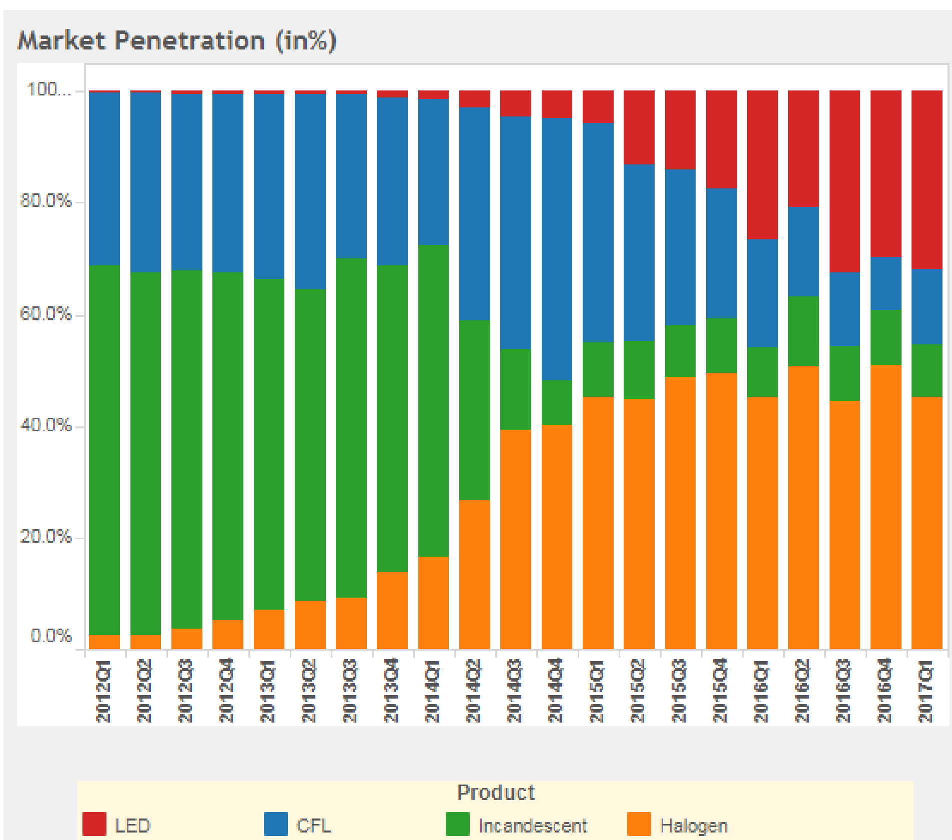
As described in Section 3.2, while LED adoption increases each year in all scenarios, the *extent* of this increase varies under each scenario. This leads to the following differences in results:

- Under the scenarios developed based on past trajectories, (Scenarios 1 and 2), lighting electricity use would drop to 852 - 883 kWh/yr for the average CA household by 2018. Statewide residential lighting electricity use would decline to 11,702 - 12,008 GWh. California would achieve a 45-47% reduction in residential lighting electricity by 2018, falling slightly short of the 50% goal. We view this range as the most likely outcome, since we developed these scenarios based on recent trajectories (and accounted for the effect of Title 20 on GSLs in 2018).

- Under the two scenarios where LED adoption rate increases faster than past trajectories (Scenarios 3 and 4), average household lighting electricity use would drop to 806 - 852 kWh/year by 2018. Statewide residential lighting electricity use would decline to 10,685 - 11,296 GWh. California would achieve its AB 1109 goal with a residential lighting electricity use reduction of 50-54% by 2018. We view these as possibilities, but changes in manufacturer's offerings (beyond TRC's forecast for GSLs in 2018 to meet Title 20), retailers' purchasing and stocking patterns, and/or customers' purchasing preferences would need to occur to cause a faster increase in LED adoption.
- Under the most optimistic scenario for both LED adoption rates and early retirement of less efficient lamps (Scenario 5), average household lighting electricity use would drop to 668 kWh/year by 2018. Statewide residential lighting electricity use would decline to 8,861 GWh. California would exceed its AB 1109 goals with a 68% reduction of residential lighting electricity use by 2018. Under this scenario, customers would retire 25% of working incandescent, halogen, and CFL lamps early, so would increase their total number of lamp purchases compared with past trajectories. In addition, almost all of these lamp purchases would be LEDs, and 60% of these LEDs would replace working lamps. This is possible if customers are motivated to buy (and install) LEDs in bulk, and for reasons besides lamp burn out.

To provide an indication of the likelihood of each scenario, Figure 8 shows the penetration by technology as a percentage of A-lamp shipments at a national level. Although California trends do not always follow national trends, and although shipments do not equate to lamp sales, this figure shows data that are more recent than the California retailer shelf surveys (last published winter 2015/16) and TRC's sales estimates based on the winter 2015/16 shelf survey. As shown in Figure 8, LED penetration of A-lamp shipments has remained mostly level at around 30% for the past three quarters (Q3 2016 through Q1 2017). If these trends are true for California sales, then the increase in the LED adoption rate – particularly the increases assumed in Scenarios 3, 4, and 5 – may be unlikely.

Figure 8. National Market Penetration (in %) for A-lamps by Technology (Source: NEMA 2017)



4.2 Upcoming Title 20 Regulations

Under the California appliance standard Title 20-2015, all general service lamps (GSLs) manufactured on or after January 1, 2018, must meet an efficacy requirement of 45 lumens per watt, with more stringent requirements taking effect in 2019. Small-diameter directional lamps (e.g., MR-16s) must also meet new efficacy requirements.

At the federal level, a proposed EISA update (Phase 2) for 2020 may increase the efficacy requirement for GSLs to 70 lumens per watt; if this (or another proposal) does not move forward, the EISA Phase 2 backstop calls for a minimum requirement of 45 lumens per watt. These regulations will phase out all filament-based lamps (halogen and incandescent) for most general service applications.

Regarding other lamp types, EISA Phase 2 may increase the scope beyond GSLs. In January 2017, the Department of Energy (DOE) issued a revision to the definition of GSL to include reflectors and some decorative lamps; PG&E and energy efficiency advocates (e.g., Natural Resources Defense Council, Appliance Standard Awareness Project) provided comments in support of this scope expansion[13]. However, the DOE must show an increase in sales trends to remove exemptions for these lamp types, so this expansion of GSLs is not guaranteed In addition, while reflector lamps are currently exempt from EISA, the federal incandescent reflector lamp (IRL) standard has efficacy requirements for reflectors, and it is possible that the DOE will update the IRL to increase its stringency. However, both the increase in scope for EISA and the increase in efficacy required for reflectors are possible (not adopted) regulations. Consequently, TRC only accounted for the adopted Title 20 requirements for GSLs and small-diameter directional lamps in the lamp forecasts through 2018. TRC conducted an analysis of lamps in the winter 2015/16 shelf survey and estimated that 55% of available lamps will be regulated by the new Title 20 requirements. The 45% of lamps that are not regulated are non-medium-screw-based, other lamp types (such as reflectors), or in unregulated lumen bins.

If California expanded the definition of GSLs, there would be additional reductions in residential lighting electricity use. TRC calculated a rough estimate for potential electricity savings for expanding the scope of GSLs to include reflectors. Reflectors comprised 14% of lamps in the average California home in CLASS 2012 (DNV-GL 2014a; which aligns with the finding that reflectors comprised 15% of lamps in the 2015/16 winter shelf survey). TRC estimated that there would be an additional 62% of lighting electricity use savings from reflectors in 2018 if all reflectors were LEDs[14]. Multiplying 14% by 62%, expanding GSLs to include reflectors would result in an additional 9% of potential residential lighting electricity use savings in 2018. Given past lamp replacement trends (approximately 15% of lamps replaced each year), expanding the GSL scope to include reflectors would yield approximately 1% of additional annual electricity use reductions. Under higher rates of early retirement (e.g., if 30% of lamps are replaced each year), an additional 2% annual lighting electricity reductions could be achieved.

4.3 Rebated Sales Fraction and Implications for PG&E Upstream Lighting Program

Because lamp rebates can affect market adoption trends, this section discusses the number of rebates that PG&E has provided historically and provides an estimate of the fraction of residential lamps that these rebated lamps represent.

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[13] DOE 10 CFR Part 430, Energy Conservation Standards for General Service Lamps, Final Rule, p. 7289. As published in the Federal Register, Vol. 82, No. 12, January 19, 2017.

[14] This estimate is based on 40W equivalent reflectors (the largest reflector class), using the Scenario 1 market penetration forecast for the baseline case. Under Scenario 1, 40W equivalent reflectors have a weighted average wattage in 2018 of 16W (comprised of 15% 40W incandescent, 18% 29W halogen, 13% 9W CFLs, and 53% 6W LED lamps). If all reflectors were 6W LEDs, TRC calculates 62% savings from reflectors.

PG&E has historically rebated a high volume of lamps through the ULP, but has been steadily reducing the quantity of rebates. In the 2006-2008 ULP, PG&E provided a large number of CFL rebates (approximately 48 million[15]). In the 2010-2012 ULP, PG&E continued to provide CFL rebates, although at reduced levels (approximately 21 million). Since those cycles, PG&E has substantially restructured its ULP programs by slashing CFL rebates and placing a greater emphasis on LEDs. By 2015, PG&E rebated 0.5 million CFLs and 2.5 million LEDs.

As described in Section 3.3, TRC divided the number of PG&E rebated lamps by our high-level estimates of total residential lamp sales in PG&E territory to calculate the fraction of lamp purchases that were rebated for select years. Note that these are rough approximations and intended to describe general trends, rather than provide precise percentage values. TRC estimates that:

- In 2008, PG&E households purchased 57 million lamps, and PG&E rebated 26 million CFLs. Thus, PG&E-rebated CFLs represented approximately one-half (45%) of all lamp purchases. This high level of market intervention by PG&E and other California utilities contributed to the significant increase in CFLs in California. For example, the in-home CLASS surveys conducted in California in 2005 and 2012 found that CFL socket saturation increased from 9% in 2005 to 29% in 2012 (DNV-GL 2014a).
- In 2012, PG&E households purchased 51 million lamps, and PG&E rebated 5 million CFLs. Thus, PG&E-rebated CFLs represented approximately one-tenth (10%) of all lamps.
- In 2015, PG&E households purchased 42 million lamps, and PG&E rebated 3 million lamps (primarily LEDs). Thus, PG&E-rebated lamps represented less than one-tenth (7%) of all lamps purchased.

Figure 9 summarizes these findings.

Figure 9. PG&E Rebated Lamps as a Percent of Total Lamps Purchased by PG&E Residential Customers

Year	Estimate of All Lamps Purchased by PG&E Res Customers (Millions)	PG&E Rebated Lamps (Millions)	Estimate of Rebated Lamps / All Lamps Purchased (%)
2008	57	26	45%
2012	51	5	10%
2015	42	3	7%

While the values in Figure 9 are high-level estimates, they illustrate the sharp reduction in the number of rebates provided by PG&E, and the significant decline that these rebated lamps represent of all lamps purchased. Previous ULP impact evaluations have found that while there is significant free ridership, the ULP has resulted in a greater uptake of high efficacy lamps and contributed to lighting electricity savings (DNV-GL 2010, DNV-GL 2014b, and DNV-GL 2017). TRC and PG&E have also described previously how past declines in high efficacy lamp availability is likely due to a decline in Investor Owned Utility (IOU) rebates (Goebes et al., 2016). The relatively small number of PG&E rebated lamps (primarily LEDs) is unlikely to have the significant impact on the market that PG&E CFL rebates had almost a decade ago.

In addition, a study done by Puget Sound Energy (PSE) indicates that rebated LED multi-packs can encourage early retirement. In a pilot program, PSE emailed their customers a promotion for an electronic rebate for a 6-pack of LEDs. A few weeks later, PSE sent a follow-up electronic survey to rebate participants, which included

[15] All numbers of rebated lamps shown in this section reflect the number of lamps assumed to be purchased by residential customers only.

questions regarding what the customers would have purchased in the absence of the promotion, and how many of the rebated LEDs they had installed. Based on the 550 survey responses:

- Approximately half (52%) reported they would not have purchased any lamps (of any technology) in the absence of the rebate, and another 22% reported they would have purchased fewer lamps. Most of the remainder would have purchased different lamps (CFLs: 9% or different LEDs: 7%).
- Almost half (44%) reported they had installed all six LEDs, and almost all (86%) had installed at least two LEDs.

Since CLASS 2012 (DNV-GL 2014a) found approximately one empty socket per household, the combined results indicate that many of the participants replaced working lamps with the rebated LEDs. This indicates that rebates can influence customers to purchase LEDs and install them through early retirement of less efficient lamps.

5. Conclusions

This analysis found that, while California has made substantial progress in reducing residential electricity use, California will achieve slightly less residential lighting reductions (45-47%) than the AB 1109 goal (50%) under Scenarios 1 and 2 (based on recent trajectories). It is possible for California to meet or exceed its AB 1109 goals (under Scenarios 3, 4, or 5). But these more optimistic scenarios would require a substantial increase in either the LED adoption rate or early retirement rates. A considerably larger market intervention than the current IOUs' ULP would help push the market towards the higher energy savings scenarios.

Utility rebates can increase penetration of efficient lamps sales, and rebates for multi-pack LEDs may encourage early retirement. However, the current scale of the ULP is small (approximately 7% of lamp sales in 2015 for PG&E), so is likely to have a much smaller impact on the market compared with a decade ago, when rebated CFLs represented almost half of all lamps purchased in California (based on 2008 estimates). Although Title 20 will have a significant impact on general service lamps beginning in 2018, utility rebates, education, or other interventions could continue to play an important role for non-GSLs, particularly if the scope of EISA Phase 2 is not expanded. In addition, utility programs can continue to play an important role in supporting state and federal codes and standards that increase efficiency requirements for residential lighting products, including the current effort to expand the federal definition of GSLs to include reflectors and some decorative lamps.

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7. APPENDIX A. STUDY LIMITATIONS AND COMPARISON OF FINDINGS

7.1 Overview of Study Limitations

TRC made various assumptions when developing this analysis.

These assumptions include the following for the lamp replacement model:

- Total lamps purchased each year per home, which depends on various factors including the number of sockets in a home, the effective useful life of each technology, and early retirement rates;
- The percent of lamps purchased by technology;
- Lamps installed from storage versus recently purchased lamps; and
- The average HOU that households operate lamps.

It is difficult to identify whether these assumptions in the lamp replacement model led to an overestimate or underestimate of residential lighting electricity reductions.

In addition, due to scope limitations, TRC's lamp replacement model only considered lamps in existing homes (i.e., assumed that lamp installations in new homes followed the same trends as lamps in existing homes). This assumption led to a slight underestimate of residential lighting electricity reductions. However, TRC assumed that the number of lamps in the average California household remained the same as what DNV-GL found in 2012 (in CLASS 2012), although the average number of lamps in California households increased from 2005 (40.6 in the CLASS 2005) to 2012 (46.1 in CLASS 2012) (DNV-GL 2014a). If this trend continued, the average number of lamps increased since 2012, so TRC's assumption for the average lamps would have led to an overestimate of residential lighting electricity reductions.

TRC used the most relevant and recent data available to develop assumptions for the inputs described above, and we describe our source of assumptions in Section 8. However, due to the number of assumptions in our methodology, results should be viewed as high-level estimates. It is difficult to identify whether this analysis underestimated or overestimated residential lighting electricity reductions.

7.2 Comparison to 2010 RASS Findings

As a methodology check, TRC compared our results to estimates in the 2010 Residential Appliance Saturation Study (RASS, based on data collected in 2009). The 2010 RASS study estimated that residential lighting electricity use averaged 1,385 kWh/yr per household in 2009, based on the study's findings that average household electricity use was 6,296 kWh/yr, and that lighting comprised 22% of electricity use (DNV-GL 2010, Page H-1).

As described in section 8.1, TRC estimated that average lighting electricity use was 1,344 kWh/yr per household in 2012. Consequently, TRC's estimate of the average household lighting electricity use in 2012 is very similar to the RASS estimate for 2009. **In general, the similarity of results indicates that the TRC estimate of residential lighting electricity use is reasonable.**

TRC had expected that our estimate for 2012 would be lower than the RASS estimate for 2009, because data indicate that CA households replaced a significant number of incandescent lamps with CFLs from 2009 to 2012. For example, the CLASS 2005 and 2012 study found that homes had an average of 3.5 CFLs in 2005, but 13.1 CFLs in 2012 (DNV-GL 2014a, Table 42). In addition, PG&E and the other electric IOUs provided tens of millions of CFL rebates from 2008 through 2012. The replacement of incandescent lamps with CFLs should have caused residential lighting electricity use to decrease from 2009 to 2012.

Possible reasons why the average household lighting electricity use was not substantially lower for 2012 compared with 2009 include:

- While the overall efficacy of lamps has increased from 2009 to 2012, the number of sockets has also increased. For example, the CLASS studies found an average of 40.6 lamps in 2005 and 46.1 in 2012 (DNV-GL 2014a, Table 42). Consequently, total lighting electricity use has stayed the same because increases in the number of lamps offset efficiency gains.
- At least one of the estimates of residential lighting electricity use may be inaccurate (i.e., results may not have accurately reflected market conditions, due to an imprecise method, biased sample, or other reason). Because CLASS collected data using an on-site survey, while RASS used a phone survey, the CLASS data may be more reliable.

8. Appendix B. Detailed Methodology

To estimate residential lighting electricity use, TRC developed a model of lamp installations in the average California household. As an overview, TRC:

1. Used the lamp installations found in the average California household based on the CLASS 2012 in-home survey (DNV-GL 2014a) to develop an inventory of existing lamps for 2012;
2. Projected the 2012 lamp inventory forward to 2016, based on assumptions of
    a. Lamp removal due to burn out (generally based on measure life) and early retirement assumptions; and
    b. Lamp replacements based on our lamp sales estimates for 2013 through 2016. TRC developed sales estimates based on lamp availability by market channel in the California retail shelf surveys (DNV-GL, ongoing), and adjusted availability data to sales based on consumer preferences for purchasing lamps in each channel (DNV-GL 2016). Section 8.4 provides more detail on the sales estimates methodology.
3. TRC then developed scenarios for lamp purchases in 2017 and 2018.

For both the past estimate of residential lighting electricity use, and forecasted use, TRC assumed the HOU found in the 2008 Residential metering study (Gaffney 2010). In addition, TRC assumed that the number of linear fluorescent lamps stayed constant at 5.1 per household (based on CLASS 2012, DNV-GL 2014a), and that each linear fluorescent lamp uses 34 Watts (typical for a T8 lamp) each year.

The following sections provide more detail on each step.

8.1 2012 Average Lighting Electricity Use

TRC used the lamp installations found in the average California household in the CLASS 2012 in-home survey (DNV-GL 2014a) to develop an inventory of existing lamps for 2012. TRC multiplied the installed lamps by the HOU found in the 2008 Residential metering study (Gaffney 2010) to estimate kWh per year. TRC developed two models:

- At the whole house level: i.e., assuming 22 incandescent, 14 CFLs, 4 halogens, 5 linear fluorescents, 0.5 LEDs per home from CLASS 2012. TRC multiplied the average wattage for each lamp technology by the average HOU for all lighting (1.9 hr/day).
- At the room by room level. For example, for all bathrooms in a home, CLASS 2012 found 5.4 incandescent, 0.4 halogens, 0.5 linear fluorescents, 0.05 LEDs on average. TRC multiplied the number of lamps, by the average wattage for each lamp technology, by the average hours of use for <u>bathrooms specifically</u> (HOU = 1.4). TRC used this approach for all rooms, and for the exterior.

There was very little impact on results between the whole house and room-by-room approach. Both show ~1,400 kWh/yr for the average CA household for residential lighting for 2012. This indicated that, at least as of 2012, consumers were not installing high efficacy lighting (primarily CFLs at that time) with strong preferences as to room types. This is supported by the fraction of CFLs found in each room in CLASS 2012: for most rooms, CFLs were ~25-35% of installed lamps. Because the results were similar, and the first approach (the "whole house" approach) was much simpler, TRC used the whole house approach for its lamp replacement model.

Using the whole house model, TRC estimated average household lighting electricity use was 1,344 kWh in 2012.

8.2 2013-2016 Lamp Installations and Average Lighting Electricity Use

TRC projected the 2012 average inventory of lamps forward to 2016, based on assumptions of lamps removed (in total and by technology) and replacement lamps. TRC projected our model forward from 2012 to 2016, by assuming that residential customers:

- Removed lamps primarily because of burn-out, with a small amount of early retirement. TRC assumed that:
  - Burn out rates were based on the effective useful life (EUL) of each lamp technology: 3.6, 5.8, 14, and 20 years for incandescent, halogen, CFLs, and LEDs, respectively.
  - Customer would primarily remove lamps because of lamp burnout. However, TRC assumed a small amount of early retirement so that the total number of lamps purchased at the statewide level in 2015 was approximately equal to the number of lamps sold in 2015 according to the LightTracker report and U.S. census data: 9 lamps per California household[16]. For total lamp purchases to equal 9 in 2015, TRC calculated that the weighted average early retirement was 6%. TRC used our best industry judgment to develop the following assumptions for early retirement at the technology level:
    - 7% for incandescent lamps, because most customers understand that incandescent lamps are not energy efficient, and replacing them can reduce their energy bills.
    - 1% for halogen lamps, because many manufacturers are marketing these lamps as "eco-friendly", so customers may not remove them as quickly as incandescent lamps.
    - 7% for CFLs, because customers have reported dissatisfaction with CFL light quality (DOE 2014).
    - 1% for LEDs, because customers are generally satisfied with LEDs (DNV-GL 2017) and recognize they are energy efficient.
- Replaced lamps by purchasing new lamps. For simplicity, TRC ignored lamps in storage and assumed that all lamps installed were recently purchased. For each year from 2013 to 2016, TRC developed lamp sales estimates based on results of California shelf surveys conducted between summer 2013 and winter 2015/16. Section 8.4 describes TRC's method for estimating lamp sales for each year.

Using this approach, TRC estimated average household lighting electricity use was 1,263 kWh in 2013; 1,194 kWh in 2014; 1,121 kWh in 2015, and 1,050 kWh in 2016.

8.3 2012-2016 California Residential Lighting Electricity Use

To estimate statewide residential lighting electricity use, TRC multiplied the average residential lighting electricity use by the number of households in California. TRC developed assumptions for the number of households as follows:

- The U.S. census found the number of occupied housing units ("households") in California was 12.6 million for 2012 and 12.9 million for 2015. These data indicate a 2.7% growth in households over 3 years, or an average annual growth of 0.9%.
- TRC used the 0.9% annual growth rate to project the number of households for each year to 2018.

[16] Excludes linear fluorescent lamps, since these are not included in the LightTracker report.

Figure 10 presents the resulting number of households in CA. This figure includes the population estimates used for past residential lighting electricity use (2012-2016) and for the forecasting scenarios (2017-2018).

Figure 10. Number of California Households, 2012 - 2018

Year	Number of CA Households
2012	12,552,658
2013	12,667,224
2014	12,782,836
2015	12,899,503
2016	13,017,235
2017	13,136,042
2018	13,255,933

By multiplying the results of lamp installations per household (Sections 8.1 and 8.2) with the number of households in California (Figure 10), TRC estimated lighting electricity use for 2012 through 2016, as shown in Figure 11.

Figure 11. California Residential Lighting Electricity Use, 2012 - 2016

Year	Average Household Lighting Electricity Use (kWh)	Number of CA Households	California Residential Lighting Electricity Use (GWh)
2012	1,344	12,552,658	16,871
2013	1,263	12,667,224	15,999
2014	1,194	12,782,836	15,258
2015	1,121	12,899,503	14,458
2016	1,050	13,017,235	13,666

8.4 Methodology for Estimating Lamp Sales for 2013-2016

8.4.1 Data Sources and Purpose of Sales Multipliers

The California shelf surveys provide valuable data of lamp availability on retailers' shelves. However, 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[17]. 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.

Figure 12 illustrates the motivation for these multipliers. This figure compares the percent of all 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 2016).

Figure 12. Lamps by Channel in Winter 2015/16 Shelf Survey Compared with Consumer Purchasing Preferences

	Disc.	Drug	Grocery	Hardware	Home Impr.	Mass Merch.	Memb. Club	Total
Lamps in shelf survey	1,032,504	957,556	3,648,138	2,159,511	3,226,312	6,209,000	491,391	17,724,412
Lamps in winter 2015/16 shelf survey (%)	6%	5%	21%	12%	18%	35%	3%	100%
Lamps purchased in channel (%) based on consumer phone survey (DNV-GL 2016)	2%	2%	2%	9%	57%	16%	12%	100%

Figure 12 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 would be over-represented since 21% 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, since these channels have lower availability in the shelf survey (18% 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 provides a very wide variety of lamp options, so this channel may offer a product solution to meet most consumers' needs. In contrast, some of the other channels are limited in the lamp variety on the shelf, so may not offer a viable replacement lamp under some circumstances.

[17] 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 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.

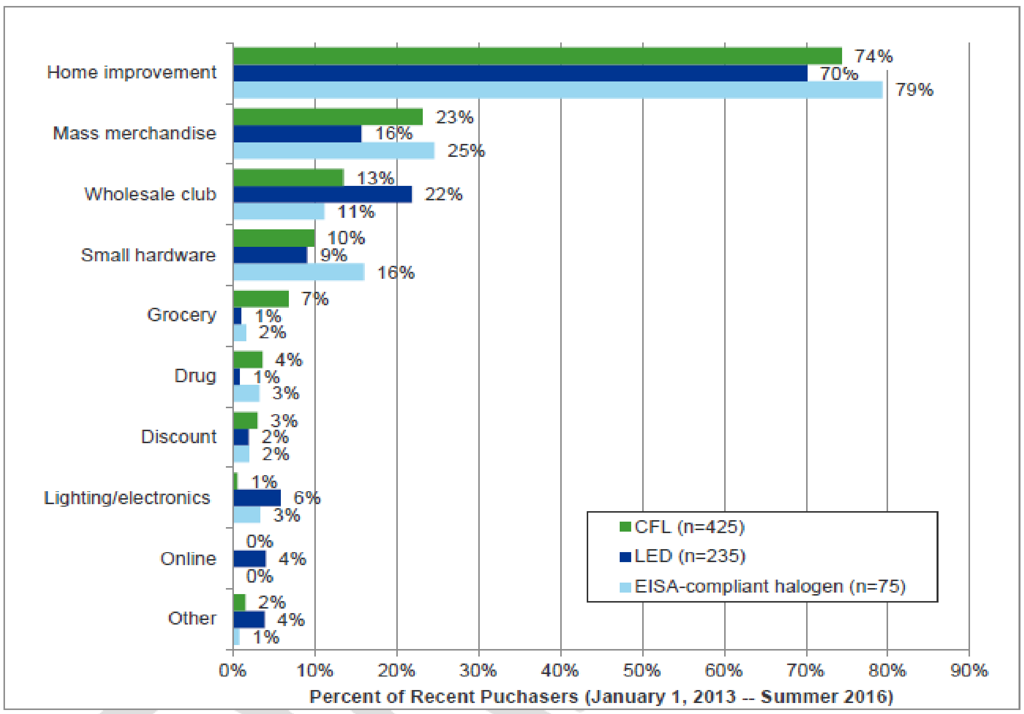
8.4.2 Description of Calculations

This section presents the calculation of the sales multipliers.

The consumer telephone survey (DNV-GL 2016) asked consumers in which channels they recently purchased lamps. Respondents could select multiple channels. Figure 13 provides the raw survey results. Respondents could provide multiple responses to the question.

Figure 13 Results of Consumer Survey on Channel Preference (DNV-GL 2016)

Figure 50: Recent purchase locations (between January 1, 2013 and summer 2015) of CFLs, LED lamps, and EISA-compliant halogen lamps among PG&E, SCE, and SDG&E residential electric customers, 2015 (consumer telephone surveys)



The survey was conducted relatively recently (2013 to 2015) 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 utility 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 2016) 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 14 and described here:

- The first set of rows in Figure 14 ("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 could 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 14: "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 sales estimates from the LightTracker report and assumed that consumers purchase incandescent lamps according to the channel preferences they identified for halogen lamps. Figure 14 shows the results in the row, "Normalized Preference", which represents the fraction of sales we estimate occurs in each channel.

Figure 14. Consumer Purchasing Preferences (DNV-GL 2016) and Subsequent Sales Multiplier

Description	Technology or Calculation	Disc.	Drug	Grocery	Hard-ware	Home Impr.	Mass Merch.	Memb. Club	Other	Total
Consumer Purchasing Preference (DNV-GL 2016)	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%

8.4.3 Lamp Sales Estimates for each Shelf Survey

Calculation and Results for Winter 2015/16 Sales Multipliers

TRC used the Normalized Preferences to adjust the shelf survey results for an estimate of lamp sales, as described here and illustrated in Figure 15.

- 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 14) 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 15, 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. TRC rounded all lamp numbers to the nearest whole number. Consequently, there are some discrepancies between the lamp sales numbers and what would be calculated using the rounded (interim) values in Figure 15.

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 15. Calculation of Lamp Sales based on Channel Preference through TRC Sales Multiplier

	Disc.	Drug	Grocery	Hardware	Home Impr.	Mass Merch.	Memb. Club	Total	% of Total Lamps
Lamp Availability per Channel based on Winter 2015/16 Shelf Survey									
Incandescent	748,156	279,840	1,314,030	928,080	877,830	1,962,965	1,421	6,112,322	34%
Halogen	69,086	284,580	739,234	415,826	698,973	1,913,162	812	4,121,672	23%
CFL	203,733	353,813	1,324,736	479,642	502,643	1,410,011	141,264	4,415,843	25%
LED	11,530	39,323	270,138	335,964	1,146,865	922,862	347,894	3,074,576	17%
Total	**1,032,504**	**957,556**	**3,648,138**	**2,159,511**	**3,226,312**	**6,209,000**	**491,391**	**17,724,412**	**100%**
Lamps in Shelf Survey (%)	6%	5%	21%	12%	18%	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 Lamp Sales Multiplier: Normalized Preference / Lamps in Shelf Survey	0.3	0.4	0.1	0.8	3.1	0.5	4.2		
Estimated Lamp Sales per Channel based on Consumer Channel Preference									
Incandescent	217,592	98,686	133,220	706,828	2,748,631	911,535	6,033	4,822,525	27%
Halogen	20,093	100,358	74,946	316,694	2,188,600	888,407	3,446	3,592,543	20%
CFL	59,253	124,773	134,305	365,297	1,573,857	654,761	599,832	3,512,079	20%
LED	3,353	13,867	27,387	255,871	3,591,023	428,546	1,477,217	5,797,264	33%
Total	**300,291**	**337,685**	**369,858**	**1,644,689**	**10,102,111**	**2,883,249**	**2,086,527**	**17,724,412**	**100%**

The calculations maintain the total lamp sales observed in the shelf survey (17.7 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 3.6 million lamps to 369,858 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 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 predominantly low efficacy lamps (e.g., grocery) decreased, and sales in channels with predominantly high efficacy lamps (e.g., membership club) increased. Consequently, TRC's adjustments result in an *increase* in sales of high efficacy lamps. Figure 15 shows that the distribution of LED lamps has approximately doubled from 17% (for availability) to 33% (for sales) through this calculation, and the other technologies have decreased to compensate. Incandescent lamps had the largest reduction by percentage, from 34% (for availability) to 27% (for sales).

Another way to interpret TRC's results is as follows: The shelf survey estimated 17.7 million lamps on California retailer's shelves at the time of the shelf survey. TRC's estimates indicate that, in the time for 17.7 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 approximately doubled LEDs).

All Sales Multipliers

TRC calculated different sales multipliers for each shelf survey, because the total number of lamps varies by shelf survey. However, results were similar for the different shelf surveys in this analysis. Figure 16 shows the sales multipliers for each shelf survey, and resulting estimates of lamp sales for each survey. For all multipliers, TRC assumed the consumer purchasing preferences shown in the last row of Figure 14 based on the DNV-GL (2016) telephone survey.

In Figure 16, 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. TRC rounded all lamp numbers to the nearest whole number. Consequently, there are some discrepancies between the lamp sales numbers and what would be calculated using the rounded (interim) values in Figure 16.

Figure 16. Sales Multipliers and Resulting Sales Estimates for Shelf Surveys

Shelf Survey	Metric	Technology	Discount	Drug	Grocery	Hardware	Home Improv.	Mass Merch.	Memb. Club	Total
2013 Summer Shelf Survey	Lamp Availability	Incandes.	1,359,827	630,709	2,305,040	1,266,257	1,143,668	2,030,229	0	8,735,731
		Halogen	45,465	78,028	310,291	353,135	515,003	1,421,424	7,288	2,730,634
		CFL	190,664	401,054	2,249,199	522,691	756,203	1,432,703	294,345	5,846,859
		LED	0	22,902	32,396	36,985	130,547	82,690	130,491	436,010
	Total Available		1,595,956	1,132,693	4,896,926	2,179,068	2,545,421	4,967,046	432,123	17,749,234
	Availability (%) by Channel		9%	6%	28%	12%	14%	28%	2%	100%
	Sales (%) by Channel		2%	2%	2%	9%	57%	16%	12%	
	Sales Multiplier		0.2	0.3	0.1	0.8	4.0	0.6	4.8	
	Lamp Sales Estimates	Incandes.	256,220	188,294	174,340	957,068	4,545,278	1,180,149	0	7,301,350
		Halogen	8,567	23,295	23,469	266,908	2,046,774	826,258	35,238	3,230,508
		CFL	35,925	119,732	170,117	395,063	3,005,375	832,814	1,423,249	5,982,274
		LED	0	6,837	2,450	27,954	518,832	48,067	630,963	1,235,103
	Total Sold		300,712	338,158	370,376	1,646,993	10,116,258	2,887,287	2,089,450	17,749,234
2014/15 Winter Shelf Survey	Lamp Availability	Incandes.	1,194,562	452,077	1,312,109	1,111,993	1,030,943	1,633,825	0	6,735,510
		Halogen	28,396	349,011	786,454	476,161	568,883	1,587,761	75	3,796,741
		CFL	366,606	385,244	750,748	428,290	580,718	1,027,815	198,634	3,738,055
		LED	1,347	33,677	97,443	102,899	413,018	394,571	285,604	1,328,559
	Total Available		1,590,912	1,220,009	2,946,754	2,119,343	2,593,561	4,643,972	484,313	15,598,865
	Availability (%) by Channel		10%	8%	19%	14%	17%	30%	3%	100%
	Sales (%) by Channel		2%	2%	2%	9%	57%	16%	12%	
	Sales Multiplier		0.2	0.2	0.1	0.7	3.4	0.5	3.8	
	Lamp Sales Estimates	Incandes.	198,439	110,124	144,938	759,462	3,534,039	892,728	0	5,639,730
		Halogen	4,717	85,018	86,873	325,205	1,950,113	867,559	286	3,319,770
		CFL	60,900	93,844	82,929	292,510	1,990,683	561,602	753,135	3,835,604
		LED	224	8,203	10,764	70,277	1,415,811	215,595	1,082,886	2,803,761
	Total Sold		264,280	297,190	325,504	1,447,455	8,890,646	2,537,484	1,836,307	15,598,865
2015/16 Winter Shelf Survey	Lamp Availability	Incandes.	748,156	279,840	1,314,030	928,080	877,830	1,962,965	1,421	6,112,322
		Halogen	69,086	284,580	739,234	415,826	698,973	1,913,162	812	4,121,672
		CFL	203,733	353,813	1,324,736	479,642	502,643	1,410,011	141,264	4,415,843

		LED	11,530	39,323	270,138	335,964	1,146,865	922,862	347,894	3,074,576
	Total Available		1,032,504	957,556	3,648,138	2,159,511	3,226,312	6,209,000	491,391	17,724,412
	Availability (%) by Channel		6%	5%	21%	12%	18%	35%	3%	100%
	Sales (%) by Channel		2%	2%	2%	9%	57%	16%	12%	
	Sales Multiplier		0.3	0.4	0.1	0.8	3.1	0.5	4.2	
	Lamp Sales Estimates	Incandes.	217,592	98,686	133,220	706,828	2,748,631	911,535	6,033	4,822,525
		Halogen	20,093	100,358	74,946	316,694	2,188,600	888,407	3,446	3,592,543
		CFL	59,253	124,773	134,305	365,297	1,573,857	654,761	599,832	3,512,079
		LED	3,353	13,867	27,387	255,871	3,591,023	428,546	1,477,217	5,797,264
	Total Sold		300,291	337,685	369,858	1,644,689	10,102,111	2,883,249	2,086,527	17,724,412

Methodology Check

LightTracker provides sales estimates based on Point-of-sales (POS) channels and Non-POS Channels. Appendix C provides a description of the LightTracker methodology. Figure 17 summarizes the inclusion of channels in the POS vs Non-POS data in LightTracker.

Figure 17. 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, for our estimates of all lamp sales based on the winter 2015/16 shelf survey, 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 18, the results were very similar, which indicates that the sales multiplier is a reasonable method to make adjustments to the shelf survey results.

Figure 18. 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%

8.4.4 Lamp Sales Estimates for each Year: 2013-2016

Because DNV-GL conducted its shelf surveys at different times (e.g., in the summer for 2013, and in the winter for 2014/15 and 2015/16), TRC interpolated results to estimate sales for each year between 2013 and 2016. Figure 19 shows TRC's estimates of total lamp sales each year, and the percent of sales by technology.

Figure 19. Sales Estimates for 2013 - 2016 Lamp Purchases

Year	Lamps Purchased	Sales by Technology (%)				Source for % of Sales by Technology
		Incandescent	Halogen	CFL	LED	
2013	10.4	41%	18%	34%	7%	Sales estimates based on summer 2013 shelf survey
2014	9.7	38%	20%	28%	14%	Average of sales estimates based on summer 2013 and winter 2014/15 shelf surveys
2015	9.0	32%	21%	22%	25%	Average of sales estimates based on winter 2014/15 and winter 2015/16 shelf surveys
2016	8.3	27%	20%	20%	33%	Sales estimates based on winter 2015/16 shelf survey

9. Appendix C. LightTracker Methodology

The following is a description of the LightTracker sales report methodology, provided by Apex Analytics.

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