Impact Evaluation of 2015 Upstream and Residential Downstream Lighting Programs

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1 EXECUTIVE SUMMARY

This report presents an impact evaluation of the California investor-owned utilities' (IOU) 2015 upstream and residential downstream lighting programs. Upstream programs typically provide incentives to manufacturers (and in some cases, retailers) to encourage stocking of energy-efficient technologies, while downstream programs typically provide incentives directly to utility customers. DNV GL conducted this evaluation as part of the California Public Utilities Commission (CPUC) Energy Division (ED) Evaluation Measurement & Verification Work Order ED_I_LTG_4: 2013-2015 Lighting Impact Evaluation and Market Research Studies.

Our evaluation addresses all upstream lighting measure groups[1] aimed at the residential and nonresidential sectors and all downstream lighting measures targeted at the residential sector. For all upstream residential measures, we present the energy savings and peak demand reductions that these measures achieved relative to technologies that they replaced (gross savings), as well as the energy savings and peak demand reduction these measures achieved relative to products that would have been purchased in the absence of the programs (net savings). The energy savings and peak demand reductions from upstream residential measures account for the majority of savings from the upstream lighting program. Nonresidential measures and downstream residential measures account for a small percentage of overall program savings, so we use program planning assumptions for these measures (also known as "ex ante" assumptions) versus results from our evaluation (known as "ex post" results).

1.1 Program background

Together, upstream and residential downstream lighting measures account for between 4% and 18% of each IOU's reported ex ante net annual electric savings, and between 2% and 11% of each IOU's net peak demand reductions (Table 1). For comparison, during the 2013-14 program period, upstream and residential downstream lighting measures accounted for 9% to 18% of each IOU's reported net energy savings and 7% to 16% of each IOU's reported net peak demand impacts.

Table 1. Summary of IOU-reported ex ante net annual savings from upstream and residential downstream lighting measures, 2015*

IOU	IOU Reported Net Annual Savings					
	Total Portfolio		Upstream / Residential Downstream Lighting		Upstream / Residential Downstream Lighting as Percent of Total Portfolio	
	Energy (GWh)	Peak Demand Reduction (MW)	Energy (GWh)	Peak Demand Reduction (MW)	Energy (GWh)	Peak Demand Reduction (MW)
PG&E	1,146.25	244.64	43.66	5.90	4%	2%
SCE	1,183.52	245.45	211.52	28.15	18%	11%
SDG&E	243.00	53.47	33.07	4.43	14%	8%
Statewide	**2,586.53**	**549.64**	**288.25**	**38.48**	**11%**	**7%**

* Ex ante data used in this table and throughout the report were final as of October 6, 2016.

[1] The term "measure" refers to a specific lamp type (such as a 9-Watt light-emitting diode [LED] A-lamp). We collapse these into measure groups—such as "LED A-lamp (all wattages)," which consists of similar measures (for example, 3-Watt LED A-lamps, 9-Watt LED A-lamps, and so on).

Upstream lighting measures fall into 15 measure groups. For example, the light-emitting diode (LED) reflector measure group includes all LED reflector lamp wattages and styles. While savings claims included in the IOU tracking data are based on assumptions tied to specific measure characteristics, the evaluation estimates savings at the measure group level.

This evaluation researched six upstream lighting measure groups in detail. Taken together, these measures account for 87% of ex ante net savings from upstream and residential downstream lighting measures in 2015. These include:

- Medium screw-base (MSB) compact fluorescent lamp (CFL) basic spiral[2] ≤ 30 watts (W)
- MSB CFL A-lamp ≤ 30 W
- MSB CFL reflector ≤ 30 W
- MSB CFL high-wattage (> 30 W)
- LED A-lamps of all wattages[3]
- LED reflector lamps of all wattages

Most of these measure groups accounted for more than 5% of total portfolio net savings, across IOUs. The one exception is the MSB CFL basic spiral ≤ 30 W measure group, which accounted for 3%. We evaluated this measure group because we largely performed our study methodologies in parallel for all measure groups considered a-lamp replacements (MSB CFL basic ≤ 30 W, MSB CFL A-lamp ≤ 30 W, and LED A-lamp ≤ 30 W).[4] Table 2 shows the quantity of evaluated measures for which each IOU provided incentives through its 2015 upstream lighting program by measure group and IOU.

Table 2. Quantity of lamps in evaluated upstream lighting measure groups by IOU, 2015

Evaluated Upstream Lighting Measure Group	Quantity (Number of Lamps)			Overall Quantity (Across IOUs)	
	PG&E	SCE	SDG&E	Total	% of Total
MSB CFL basic spiral ≤ 30 W	499,902	0	20,795	520,697	4%
MSB CFL A-lamp ≤ 30 W	21,610	1,126,146	265,251	1,413,007	10%
MSB CFL reflector ≤ 30 W	0	2,639,047	88,564	2,727,611	20%
MSB CFL high-wattage (> 30 W)	69,696	2,315,789	203,480	2,588,965	19%
LED A-lamp, all wattages	1,381,811	1,548,699	640,392	3,570,902	26%
LED reflector, all wattages	694,575	1,626,451	423,502	2,744,528	20%
Overall	**2,667,594**	**9,256,132**	**1,641,984**	**13,565,710**	**100%**

1.2 Evaluation objectives

The overarching goal of the impact evaluation for the 2015 upstream and residential downstream lighting measures is to verify and validate the IOU-reported energy savings and peak demand reduction estimates. The impact evaluation approach has three objectives:

[2] The CPUC defines "basic spiral CFLs" as single-wattage, non-dimmable, bare spiral CFLs of up to (and including) 30 W. For the sake of clarity, we refer to these lamps as "basic spiral CFLs" throughout the report.

[3] Note that while the CFL measure groups include MSB lamps only, the LED lamp measure groups include all base types.

[4] We provide more detail on this in Section 5.1 and Section 6 of the report.

1. Develop measure quantity adjustments, which include program invoice and application verification, an assessment of the percentage of IOU-discounted products purchased by non-IOU customers (i.e., leakage), and an assessment of the percentage of IOU-discounted products purchased by residential versus nonresidential customers.
2. Develop gross savings estimates, which include an assessment of the percentage of IOU-discounted measures installed as well as estimates of the average daily operating hours (hours-of-use, or HOU), the average percent of time that measures operate during high-use periods (peak coincidence factor, or CF), the wattage displaced by IOU-discounted measures (delta watts), unit energy savings (UES) in kWh/year and therms/year, peak demand reduction in kW/year, and lamp installation rate.
3. Develop net savings estimates, which include the percent of efficient lamps that people purchased because of program discounts, market-based UES in kWh/year and therms/year, peak demand reduction in kW/year, and a net-to-gross ratio (NTGR).

1.3 Evaluation approach

Below, we present data sources that we leveraged in this evaluation and an overview of our approach.

1.3.1 Data sources

DNV GL conducted six data collection efforts in support of this evaluation (Table 3f). We leveraged the 2016 consumer telephone surveys, in-store shopper intercept surveys, and retail lamp stock inventories as inputs to a model. This model simulates shopper decision-making regarding their lamp purchases and provides estimates of the percent of the total lamp sales for which a particular lamp type accounts. As we discuss in more detail below, these market share estimates supported our assessment of the program's savings. In addition to these primary data sources, we also leveraged secondary sources such as 2015 program tracking data and past evaluation studies and reports.

Table 3. Primary data sources: upstream and residential lighting programs impact evaluation, 2015

Data Source	Timing	Sample Size
2015 consumer telephone surveys	Summer, 2015	1,016
2016 consumer telephone surveys	Fall, 2016	578
2016 consumer online surveys	Fall, 2016	313
In-depth telephone interviews with lamp suppliers	Fall, 2016	27
Retail lamp stock inventories	Winter 2015-16	207
In-store shopper intercept surveys	Winter 2015-16	431

1.3.2 Method

We used the following approach to achieve the study's objectives:

1. Develop measure quantity adjustments
    a. **Residential versus nonresidential upstream lighting purchases.** We adjusted the percentage of upstream lamps that customers installed in residential and nonresidential applications.
    b. **Invoice verification**. Using data from prior evaluations, we confirmed that lamp quantities and types in the IOUs' program records matched the quantities and types on the lamp suppliers' shipping invoices.
    c. **Leakage**. We estimated the percentage of IOU-discounted lamps that were installed outside of California IOU territory using findings from prior evaluations.
2. Develop gross savings inputs

a. **Hours of use and use at peak (high-use) periods.** We leveraged data from in-home lamp metering efforts in prior studies to estimate daily hours of use for California IOU customers' lights, and the overlap of this usage with periods of highest energy demand.

b. **Delta watts.** We used results from a residential on-site survey to estimate the average wattage of lamps installed in IOU customers' homes. This is the average wattage of lamps that program-discounted lamps replaced. The difference between the average program-discounted lamp's wattage and the average replaced lamps' wattages is called "delta watts."

c. **Lighting interactions with heating, ventilation, and cooling (HVAC) system usage**. Because CFLs and LED lamps are more efficient than traditional incandescent lamps and their newer, slightly more efficient counterparts[5], they generate less heat. When lighting generates less heat, it creates small reductions in electricity usage during the summer (because of a slightly reduced need to cool the space). Less heat from lighting also increases gas consumption slightly in the winter (because of a slightly increased need to heat the space). The industry refers to these impacts as "HVAC interactive effects". We applied ex ante assumptions to calculate HVAC interactive effects.

d. **Unit energy savings**. We used the three parameters to calculate the energy saved by each program lamp—hours of use, delta watts, and HVAC interactive effects. We refer to the savings per program-discounted lamp as "unit energy savings" (UES).

3. Develop net savings inputs

a. **Calculate program-attributable sales of each program lamp type as a percent of program volume (NTGRq)**. Customers still would have purchased some efficient lamps in the absence of program discounts. We simulate consumer decision making to estimate the degree to which customers would have purchased each lamp type with program lamps available and without program lamps available. We adjusted our model simulations using details regarding stocking practices that influenced lamp availability from in-depth telephone surveys with lamp manufacturers and retail representatives. The ratio of program lamp purchases that would have been a different lamp technology without the program to the quantity of all program lamps is called the "quantity net to gross ratio" (NTGRq).

b. **Calculate the wattage of the lamp purchases that program lamps displaced (NTGRu)**. The gross savings calculations assume that purchases made in the absence of the program would have the same technologies and wattages of lamps that were previously installed. However, the wattage of a lamp that was installed may not necessarily be the wattage of the lamp that the customer would have purchased in the absence of the program. We used the same modelling process that estimates the NTGRq to estimate the degree to which program lamps displaced competing lamp technologies. We then used retail lamp stock inventory data to estimate the wattages of those displaced lamps. We were thus able to calculate the amount of energy that the program lamps saved relative to the displaced purchases. We call this factor the "net unit energy savings." The ratio of the net unit energy savings to the gross unit energy savings is called the UES net-to-gross ratio (NTGRu).

c. **Calculate the overall net to gross ratio (NTGR)**. We multiplied the NTGRq by the NTGRu to estimate the overall NTGR. We then applid the overall NTGR to the gross savings estimate to produce the final net energy savings that the program achieved.

1.4 Evaluation results

In this section, we summarize the evaluation results, including gross savings, net savings, and net-to-gross ratios (the ratio of net savings to gross savings).

[5] This refers to lamps that comply with the standards set forth in the 2007 Energy Independence and Security Act (EISA), a federal standard that regulates lamp efficiency.

1.4.1 Gross Savings

Table 4 provides an overview of ex ante and ex post gross annual energy savings, demand reductions, and realization rates[6] for 2015 evaluated upstream lighting measures across IOUs. As the table shows, the IOUs achieved ex post gross annual energy savings of more than 433 GWh for 2015 measures. Key drivers for the gross savings results include:

- **Difference in ex ante and ex post approaches to estimating gross delta watts.** Gross delta watts is the difference between program-discounted lamp wattages and the wattage of lamps they replace when installed. Ex ante estimates use a wattage reduction ratio while ex post uses a difference between the average program wattage and the average installed wattage. Where program lamps had lower average rebated watts in a specific measure group (such as LED A-lamps), ex post estimates were higher than ex ante estimates, and vice versa (such as High-wattage CFLs > 30). The low wattages of program LED A-lamps and LED reflector lamps led to high gross savings results.
- **Residential/nonresidential split for SDG&E.** SDG&E's ex ante assumptions allocated all upstream lighting program lamps to the residential sector. Ex post assumptions allocated 94% to the residential sector and 6% to the nonresidential sector. Savings are generally higher in the nonresidential sector because hours of use are greater. (PG&E's and SCE's ex ante assumptions largely matched the ex post assumptions.)
- **Higher ex post CFL installation rates than ex ante for PG&E and SCE.** PG&E's ex ante installation rates for all CFL measure groups was 67% and SCE's was 77%. The ex post installation rate estimate was 95% for all IOUs. (SDG&E's ex ante CFL installation rate was 97%.)

Table 4. Ex ante and ex post gross savings and realization rates by evaluated upstream lighting measure group across all IOUs, 2015

Gross Savings Element	Evaluated Upstream Lighting Measure Group						Overall
	MSB CFL basic spiral ≤ 30 W	MSB CFL A-lamp ≤ 30 W	MSB CFL reflector ≤ 30 W	MSB CFL high-wattage (> 30 W)	LED A-lamp, all wattages	LED reflector, all wattages	
Ex Ante							
kWh	13,621,389	38,947,183	108,611,618	162,860,055	35,674,313	74,038,848	433,753,405
kW	1,864	5,402	14,624	22,502	4,853	10,313	59,558
Therms	(247,872)	(521,845)	(1,542,560)	(2,231,110)	(581,839)	(1,129,691)	(6,254,916)
Ex Post							
kWh	11,314,334	39,913,035	91,145,975	101,521,443	109,741,192	101,120,464	454,756,443
kW	1,762	5,754	13,469	16,607	12,987	13,124	63,703
Therms	(183,691)	(516,867)	(1,141,932)	(983,407)	(2,008,537)	(1,644,388)	(6,478,823)
Gross Realization Rate							
kWh	83%	102%	84%	62%	308%	137%	105%
kW	95%	107%	92%	74%	268%	127%	107%
Therms	74%	99%	74%	44%	345%	146%	104%

1.4.2 Net Savings

We developed two factors to calculate net savings (as we explained above in Section 1.3): the NTGRq and NTGRu. Both of these factors are essential when interpreting the net savings results. The NTGRq is the share of program-discounted lamps that customers would not have purchased in the absence of the program.

[6] The realization rate is the ratio of ex post savings to ex ante savings

The NTRGu is the ratio of energy savings that the program achieved in the market, compared to the energy savings that the program achieved by efficient lamps that IOU customers replaced in homes. We multiply these two factors together to estimate an overall NTGR. For example, LED A-lamps received an overall NTGR of 30% to 33%. This finding does not suggest 67% free-ridership.[7] The NTGRq (roughly 60%) suggests that the program was responsible for selling around 60% of the program LED A-lamps, meaning 40% would have sold at higher, non-program prices. The NTGRu (roughly 50%) decreases the overall NTGR further, meaning that the lamps that were displaced on the market were in general more efficient than the lamps IOU customers replaced with LED A-lamps on average. Key drivers for net savings include:

- **NTGRq: Low program influence for CFL basic spiral and high-wattage CFLs, moderate influence for LED lamps, and high influence for CFL A-lamps and CFL reflector lamps**. The NTGRq for basic spiral CFLs and high-wattage CFLs > 30 W was between 21% and 56% across all IOUs (i.e., free-ridership was high)[8]. The NTGRq for LED A-lamps was approximately 60% across all IOUs (moderate free-ridership), and between 69% and 90% for CFL A-lamps and CFL reflectors for all IOUs (low free-ridership).
- **NTGRu: The blended efficiency of program-displaced sales, and the customers who shopped in stores where program lamps were available were major drivers in the net savings results.** For measure groups where the NTGRu was low (for example LED A-lamps, 51% to 55%), the displaced sales within a replacement group (the basis for the net UES) were of lower wattages than the existing lamps installed in IOU customer residences (the basis for gross UES). This is reasonable given the market trends suggesting an upward trend in efficient lamp purchases.[9] For other measure groups where NTGRu results were fairly high (for example CFL A-lamps, 81% for SCE to 157% for PG&E), the channels that sold program lamps largely stocked non-program lamps that were less efficient than the average lamps that IOU electric customers replaced with CFLs in their households. Furthermore, the customers who shopped in stores where the program lamps were available are the true program population, and these populations may be slightly-to-very different from overall IOU populations. The NTGRu accounts for these differences.
- **Overall NTGR (NTGRq multiplied by NTGRu): When considered in terms of NTGRq and NTGRu, the overall NTGR provides insight into the relationship between gross savings estimates and net savings estimates.** Basic spiral CFLs have low NTGRq and NTGRu, which produce overall NTGR for all IOUs around 30%. Gross savings estimates for these measures were already low, so net savings dropped further. Even when available in hard-to-reach markets, this measure group had less-than-expected program impacts in 2015. The NTGRqs for LED A-lamps and LED reflector lamps are moderate, while the NTGRus for these two measure groups are fairly low for all IOUs. This finding means that the average lamp displaced by program LED lamps was of lower wattage than the average of all installed lamps across all electric IOU customers. The NTGRu adjustment should not be considered an indicator of poor program performance as the overall ex post net savings closely matches the ex ante next savings for these two measure groups. Instead, this finding suggests that future evaluations and ex ante assumptions consider evaluating gross savings in a way that more closely aligns with this net savings approach.

Below, Table 5 provides the NTGRq, NTGRu, and overall NTGR for all evaluated upstream lighting measure groups for each IOU. Note that in some instances, the overall NTGR is over 100%. An overall NTGR over 100% does not suggest spillover, but instead is a combination of low free ridership and high market-level savings.

7 Free-ridership is the percent of customers who purchased a program-discounted efficient lamp, but would have purchased the same lamp at the full retail price.

8 Note that SCE distributed many MSB high-wattage CFL > 30 W to grocery stores, where data suggest higher program attribution for this measure group than discount stores, where PG&E and SDG&E shipped the majority of this measure group.

9 Note that the gross savings realization rates are very high, so the low NTGRu and overall NTGR ultimately produce net realization rates close to 100%.

Table 5. Results for NTGRq, NTGRu, and overall NTGR for all evaluated upstream lighting measure groups by IOU (2015)

IOU / NTGR	Evaluated Upstream Lighting Measure Group					
	MSB CFL basic spiral ≤ 30 W	MSB CFL A-lamp ≤ 30 W	MSB CFL reflector ≤ 30 W	MSB CFL high-wattage (> 30 W)	LED A-lamp, all wattages	LED Reflector, all wattages
PG&E						
NTGRq	22%	70%	N/A	30%	59%	53%
NTGRu	203%	157%	N/A	105%	51%	73%
Overall	46%	110%	N/A	31%	30%	39%
SCE						
NTGRq	N/A	85%	89%	56%	60%	52%
NTGRu	N/A	81%	120%	145%	55%	74%
Overall	N/A	69%	107%	81%	33%	38%
SDG&E						
NTGRq	21%	69%	70%	35%	60%	56%
NTGRu	98%	146%	116%	161%	55%	94%
Overall	21%	101%	81%	57%	33%	52%

We used ex ante savings estimates rather than develop separate ex post estimates for residential downstream measures. We also adjusted the estimates of upstream measures purchased for residential versus nonresidential applications. Our ex post gross savings for the adjusted nonresidential upstream quantities rely upon the ex ante gross UES estimates. Table 6 shows that IOUs achieved ex post net annual energy savings of more than 260 GWh for 2015 measures.

Table 6. Ex ante and ex post net savings and realization rates by evaluated upstream lighting measure group across all IOUs, 2015

Net Savings Element	Evaluated Upstream Lighting Measure Group						Overall
	MSB CFL basic spiral ≤ 30 W	MSB CFL A-lamp ≤ 30 W	MSB CFL reflector ≤ 30 W	MSB CFL high-wattage (> 30 W)	LED A-lamp, all wattages	LED reflector, all wattages	
Ex Ante							
kWh	7,355,550	21,967,514	61,176,097	91,399,614	22,778,031	45,848,261	250,525,068
kW	1,007	3,046	8,234	12,627	3,117	6,433	34,464
Therms	(133,851)	(293,689)	(867,009)	(1,248,949)	(373,481)	(697,471)	(3,614,449)
Ex Post							
kWh	5,481,959	27,300,704	80,636,143	66,595,202	38,655,412	45,316,229	263,985,649
kW	877	3,792	11,038	10,419	4,908	6,304	37,338
Therms	(85,035)	(376,498)	(1,168,077)	(721,240)	(657,839)	(677,375)	(3,686,065)
Net Realization Rate							
kWh	75%	124%	132%	73%	170%	99%	105%
kW	87%	124%	134%	83%	157%	98%	108%
Therms	64%	128%	135%	58%	176%	97%	102%

1.5 Conclusions and recommendations

Based on the research we conducted in support of this evaluation, we developed conclusions and recommendations. These pertain to program tracking data, the program implementation strategy, and directions for future research.

We provide further detail below.

1.5.1 Tracking data

DNV GL relied upon program tracking data as the basis for measure quantities in our ex post savings analyses. Our review and analyses of the tracking data yielded the following conclusions:

- In a few cases, there were inconsistencies between the program year reported in the tracking data and the shipment year included in lamp suppliers' records.
- SDG&E and PG&E assigned incorrect measure groups to approximately 250,000 lamps based on the lamp wattage recorded in the program tracking.

Based on these conclusions, we recommend:

- **Recommendation 1.** Tracking data should consistently present measures that were truly discounted and shipped within the program year. We also recommend that Commission staff consider a careful review of claim year as a future research priority.
- **Recommendation 2.** Program administrators should consider performing additional review and accuracy checks on the measure group classifications and wattage estimates for program lamps.

1.5.2 Implementation strategy

Our analyses yielded three conclusions regarding related to three elements of the IOUs' upstream lighting program implementation strategy, including the retail channels in which the IOUs offer program-discounted lamps and the lamp types offered (CFLs and LED lamps). With regard to the retail channels, we conclude:

- Without program support, significantly fewer customers would have purchased energy efficient lamps in discount, drug, grocery, and hardware channels. The inefficient lamps that program lamps displaced in these channels were less efficient than the lamps that IOU customers replaced with efficient lamps on average. In big-box channels, freeridership was relatively high.

With regard to upstream lighting program strategy regarding CFLs, we conclude:

- The 2015 upstream lighting program appeared to drive very few basic spiral CFLs ≤ 30 W purchases. Freeridership was relatively high and net UES was relatively low.
- The program strategy to discount CFL A-lamps ≤ 30 W in discount, drug, grocery, and small hardware stores yielded favorable savings results. Freeridership was relatively low and net UES was relatively high.
- The program appears to have convinced some customers to purchase high-wattage CFLs (> 30 W) in grocery stores, but the energy savings achieved by high-wattage CFLs was lower than anticipated. Many consumers are using high-wattage CFLs to replace lamps that are less bright and lower wattage than expected. As such, while freeridership was reasonable, net UES for these measures was lower than anticipated.

With regard to upstream lighting program strategy regarding LED lamps, we conclude:

- The program appears to have moderately motivated customers to purchase LED A-lamps and LED reflector lamps by heavily discounting these products in membership club stores. Our analysis suggests that many of these purchases would have occurred at other retail channels in the absence of the program. LED A-lamps and LED reflector lamps achieved around 60% NTGRq, suggesting 40% of them were purchased by freeriders. However, many of the non-LED lamps that customers would have purchased in the absence of the program would have been more efficient than the ones that IOU

customers replaced on average, which produced low NTGRu results. The net UES estimates were highest in the hardware and discount channels and the lowest in the membership club channel.
- Consumer satisfaction with LED lamps in general was high during 2015 and 2016.

Based on the above conclusions regarding upstream lighting program implementation strategy, we recommend:

- **Recommendation 3.** The IOUs should consider shifting more of their upstream lighting program incentives toward the non-big box channels to minimize freeridership and maximize net UES. However, we acknowledge that these channels are not capable of moving a large volume of program-discounted lamps as quickly as the big box channels, so some effort may be required to strike the appropriate balance between program effectiveness and volume.
- **Recommendation 4.** The IOUs should continue shifting upstream lighting program incentives away from basic spiral CFLs ≤ 30 W.
- **Recommendation 5.** With regard to high-wattage CFLs (> 30 W) in particular, moderate freeridership suggests the IOUs could continue to influence customer purchases by providing incentives for these measures in grocery, discount and drug stores—however:

    a. Given the potentially limited applicability of these measures in PG&E, SCE, and SDG&E residential electric customer households, the IOUs should also consider the overall installation potential for these measures when establishing program quantities.

    b. Consumer survey results suggest that consumers are, in many cases, using high-wattage CFLs to replace lamps of lower brightness. For some applications, the program may be shifting consumers toward higher-wattage replacement lamps than they would choose absent the program, which may warrant further consideration from the IOUs.

- **Recommendation 6.** Despite low overall NTGRs, LED A-lamp and LED reflector lamp NTGRq results are moderate, and realization rates are high, suggesting IOUs should continue shifting upstream lighting program incentives to LED A-lamps and LED reflector lamps. The IOU's should begin to discount more mid-to-high brightness LED lamps, and future studies should explore the degree to which customers are replacing mid-to-high watt CFLs and incandescent lamps with low-watt LED lamps.

1.5.3 Future research

The research we conducted in support of this study suggested two topics that may be worthy of consideration for future research.

1.5.3.1 Channel shift

Channel shift is a form of program influence that "shifts" sales out of some retail channels and into others as a result of where program incentives are available. We investigated this phenomenon during our supplier interviews. Supplier representatives mentioned the channels most affected by the program are likely the discount, grocery, drug, and membership club channels. Channel shift effects were important in the membership club channel given that these stores sold the largest share of program lamps of any retail channel in 2015 (39% of lamps in evaluated measure groups). Based on these findings, we conclude:

- The upstream lighting program influences the retail channels through which manufacturers sell replacement lamps to PG&E, SCE, and SDG&E residential electric customers in California.

Based on this conclusion, we recommend:

- **Recommendation 7.** Future EM&V efforts should further explore channel shift effects—including the quantity of lamps shifted, the channels to and from which the shifts occur, and the measure groups most affected.

1.5.3.2 California Quality LED Lamp Specification

Starting in January 2014, the CPUC ED required that the IOUs demonstrate that the LED lamps for which they offer program incentives meet the performance requirements outlined in the California Quality LED Lamp Specification.[10] The specification's intent was to ensure that LED lamps would meet or exceed customer expectations regarding lamp performance and light quality.

The spec has no effect on energy savings, so this is ultimately not an impact evaluation issue. However, the IOUs have suggested that higher quality will yield higher LED lamp satisfaction, and repeat purchase. We asked about LED lamp satisfaction in our 2016 consumer telephone survey, and the specification's influence on LED lamp sales in our 2016 supplier interviews. Based on the results of these efforts, we conclude:

- Among the IOUs' residential electric customers who purchased LED lamps during 2015 and 2016, satisfaction was high. However, because LED lamps that meet the California Quality spec comprised such a small share of LED lamp stock among California retailers (13% as of winter 2015-16), it is unlikely that the spec is the primary driver of customer satisfaction.
- Manufacturers' representatives suggest that the upstream lighting program was the primary reason they produced LED lamps that met the spec in 2015.

Based on these findings, DNV GL recommends:

- **Recommendation 8.** Commission staff should consider pursuing a more definitive assessment of consumer satisfaction with LED lamps that do and do not meet the California Quality spec. The upcoming in-home lighting inventory and metering study is a good opportunity to perform this assessment. At this time, Commission staff plan to launch this study in 2018.

1.5.3.3 Impact Evaluation and Program Potential Research

This evaluation's research plan included an investigation to better understand the extent to which LED lamps replaced lamps before they reached their effective useful life.

- Consumer survey results suggest that 68% of LED lamps purchased by customers replaced functioning lamps. This finding suggests that there is a potential savings impact related to early replacement.
- While the above recommendations reflect a business-as-usual environment, market conditions are expected to change in 2018 due to California's Title 20 legislation. These changes are likely to dramatically limit or eliminate the potential for residential and upstream lighting program savings.
- The modelling in this report uses respondent demographics by applying coefficients, which are shown in Table 89. The underlying data, along with the 2016 consumer survey, have the potential to offer additional insights into the customer side of the lighting market, beyond the scope of this evaluation.

Based on these findings, DNV GL recommends:

- **Recommendation 9.** Future evaluations should further investigate which lamps are being replaced early. With this more complete picture, future evaluations should estimate savings impacts associated with early replacements.
- **Recommendation 10.** A potential study should be considered to estimate the remaining available energy savings potential that incorporates the impacts of Title 20 changes in 2018.
- **Recommendation 11.** The data collected to answer the research questions for this evaluation have the potential to offer additional insights into the customer and supplier sides of the lighting market. Such a study could look at customer segmentation among various retail channels, perceptions of lighting technologies, and could explore price sensitivities.

[10] CEC, 2012 and CEC, 2014.