SCE's Home Energy Report Program Savings Assessment

Ex-Post Evaluation Results for Opower-2, Program Year 2015

Final Report

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Prepared for

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Executive Summary

Background

Since December 2012, Opower has operated the Home Energy Report (HER) program, a comparative energy usage and disclosure pilot program, for Southern California Edison in the San Gabriel/Rancho Cucamonga portion of the service territory.

This report documents Applied Energy Group's evaluation of the second year of savings from the group of customers who started participating in the HER program in 2014. The 2014 HER program has been referred to as Opower-2, as it is distinct from customers who participated in 2013. Since this is the second year of treatment with the Opower-2 program group, we refer to the 2015 program as Opower-2 PY 2015.

The goal of this savings assessment was to provide ex-post estimates of savings for the period of January 1, 2015 to December 31, 2015 that are attributable to the 2015 HER program, including:

- kWh savings achieved by the program participants, minus their savings claimed by other SCE programs operating during that time;
- peak kW savings calculated two ways, applying a load factor to the kWh savings based on using SCE's load research data and direct estimation from hourly interval data, minus their kW savings claimed by other SCE programs operating during that time.

Analysis Methods

We estimated per-participant energy impacts for the HER program using two methods: difference in differences and regression modeling. Both methods used monthly billing data from pre-treatment and treatment periods. The difference in differences method provided a preliminary estimate of monthly and annual energy savings that we were able to use as an initial estimate of savings. The fixed-effects regression approach allowed us to refine the savings estimate and reduce uncertainty by accounting for more of the differences between customers.

To develop the program-level savings, we applied the monthly estimates from the regression model to the active customer accounts (to account for attrition due to customer move-outs). We then subtracted the incremental portion of savings being claimed for these participants due to their participation in SCE's other downstream (i.e., rebate) programs and upstream (price markdown) lighting program during the HER treatment period.

We also conducted two analyses to assess the peak kW impacts of the Opower-2 PY 2015 program. We made one estimate by applying an average residential class load factor to the estimated kWh savings. We also developed an estimate using interval data for the treatment and control accounts, using a difference in differences approach. For both estimates we used the 3-day heat wave, September 8-10, 2015, using the CPUC-approved DEER definition. The final peak kW results are from the interval data analysis. We contrast these approaches to determine if it is feasible to obtain reliable results through the lower cost, load factor approach.

Results

Table ES-1 summarizes the monthly and annual energy savings for the HER program treatment period, January 2015 through December 2015. It shows per-participant annual savings of 77.74 kWh or 1.0% of baseline usage, with monthly savings ranging from a low of 0.8% in March 2015 to a maximum of 1.3% in November. The table shows the estimated treatment customer average energy savings, percent energy savings, number of participants included in the analysis month, and total estimated savings for the population of participants. Averaged over all 12 months, the per-participant savings is 6.5 kWh per month. The savings are statistically significant for every month in the treatment year.

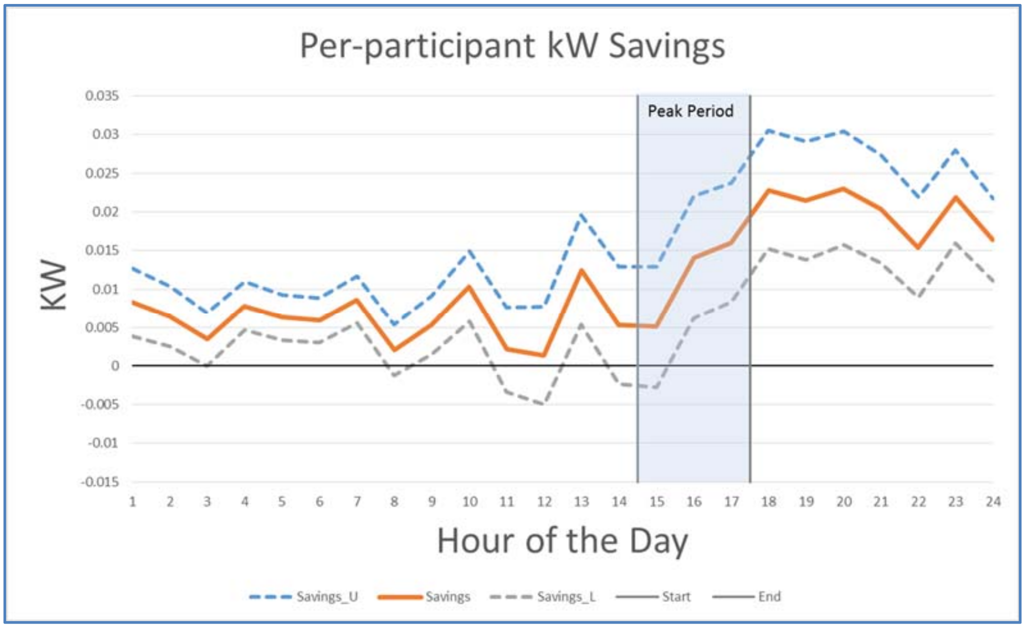
Table ES-1 Estimated HER 2015 Energy Savings

Month	Participants	Average Per-Participant Savings (kWh) [a]	% Savings	Total Savings, All Participants (kWh) [a]
January	70,537	4.90	0.89%	345,741
February	70,296	4.30	0.87%	302,422
March	70,047	4.14	0.80%	290,149
April	69,701	5.34	1.07%	372,460
May	69,400	5.95	1.19%	412,854
June	69,069	7.91	1.21%	546,319
July	68,705	9.48	1.21%	651,310
August	68,356	8.61	0.95%	588,359
September	67,963	7.80	0.83%	529,919
October	67,657	6.77	0.91%	458,189
November	67,357	6.71	1.28%	452,016
December	67,101	5.82	0.99%	390,559
Total		**77.74**	**1.01%**	**5,340,297**

[a] Total savings differences due to rounding of average per-participant displayed values

The peak kW savings results using hourly interval data yielded statistically significant per-participant savings of 0.0118 kW, a peak demand reduction of 0.43%. The 90% confidence interval is +/- 0.0071 kW. This represents the average savings across the nine hours of 2-5 pm on September 8-10, 2015. As Figure ES-1 shows, the demand savings are actually higher in the hours after the DEER-defined peak hours but are not included in the savings calculation. When the peak hour per-participant savings are multiplied by the number of participants as of September 8, 2015 (67,903), the total program peak load savings estimate is 799.6 kW.

Figure ES-1 Interval Data Peak kW Savings Per-Participant in 2015



Some customers included in the HER program also participated in other programs offered by SCE during 2015. To avoid double-counting of savings from multiple programs, savings estimated to have accrued to HER customers from their participation in downstream (rebate) programs and/or the upstream lighting program that were counted by those programs were removed from the total HER savings estimates.

Table ES-2 summarizes the the final Opower-2 PY 2015 ex-post savings results which indicate savings of 5,340 MWh for all of 2015 and peak savings of 800 kW.

Table ES-2. Total 2015 HER Program Savings

	kWh	% of Energy [a]	% of Energy Savings [b]	kW	% of Demand [a]	% of Demand Savings [b]
Opower-2 PY 2015 Savings	5,340,297	1.0%	100.0%	799.6	0.4%	100.0%
Upstream Program Savings	604,864	0.1%	11.3%	29.6	0.0%	3.7%
Downstream Program Savings	170,089	0.0%	3.2%	40.6	0.0%	5.1%
Total Program Savings [c]	**4,565,344**	**0.9%**	**85.5%**	**729.4**	**0.4%**	**91.2%**

[a] The percentages in these columns are calculated against total household energy.
[b] The percentages in these columns are calculated against total savings.
[c] Total savings difference is due to rounding.

Key Findings

There are several key findings from the results presented above:

- **Statistically significant savings in all 2015 treatment months:** We estimate average direct program annual savings of 5,340 MWh, with statistically significant savings in every single month; and 800 kW peak load savings also statistically significant over the heat wave hours.

- **Larger kWh savings in summer months:** We estimate higher per-participant kWh savings in summer months when overall usage is highest. In percentage terms, summertime savings fluctuate around the annual average of 1.0%. Both the kWh and percentage savings are lowest in March 2015, which is among the lowest usage months, and also followed a longer than usual gap between HER reports, due to the change in program year.
- **Highest kW savings occur partially outside designated peak hours:** While the DEER-defined peak period is 2-5p, in 2015, the highest savings occur after the peak hours. This may suggest that the peak period is actually shifting.
- **Monthly energy savings exceed and peak savings equal previous program year:** 2015 was the second year of treatment with the same set of Opower-2 participants. The average monthly per-participant savings increased to 6.5 kWh from 5.7 in 2014, while the peak savings remains at .012 kW. Total annual kWh savings are notably higher than last year, in large part because the program was implemented for the full year rather than only nine months in 2014. As percent of total usage, the total kWh and kW savings are the same as last year.
- **Incremental savings account for 2-3 times as much of direct savings than previous year:** Since 2015 was the second year of treatment for the Opower-2 participants, the incremental savings from participation in other SCE programs includes effects from installations in both 2014 and 2015. This, in combination with an increase in other program installations in 2015 results in much higher savings removed from the direct HER program savings.
- **The upstream savings calculation methodology very likely overstates the true incremental savings:** While we concur with the ED-approved algorithm for calculation of savings due to HER-induced lighting actions, we believe that many of the designated input values are of doubtful reliability and/or applicability to SCE’s service area and program, including number of bulbs purchased and installed, and per-bulb savings—resulting in overstatement of savings. We recommend that, as new data become available, the approved methodology should be revisited and updated.

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Chapter 1 – Introduction

Background

Since December 2012, Opower has operated the Home Energy Report (HER) program, a comparative energy usage and disclosure pilot program, for Southern California Edison in the San Gabriel/Rancho Cucamonga portion of the service territory. This program provides SCE's residential customers feedback through reports showing their household energy use and comparisons of energy use from similar neighbors. The reports also provide a personal comparison, showing the household's energy usage over time. The reports also give the recipients energy efficiency tips to promote behavior modification in achieving energy savings.

This report documents Applied Energy Group's evaluation of the second year of savings from the group of customers who started participating in the HER program in 2014. The 2014 HER program has been referred to as Opower-2, as it is distinct from customers who participated in 2013. Since this is the second year of treatment with the Opower-2 program group, we refer to the 2015 program as Opower-2 PY 2015.

The Opower-2 PY 2014 and 2015 program engaged the exact same group of residential accounts in the San Gabriel/Rancho Cucamonga portion of SCE's service territory. For Opower-2 PY 2015, the Home Energy Reports were sent out to customers beginning in March 2015 through December 2015.[1]

The program operated under a strict randomized control trial experimental design that was reviewed by the California Public Utilities Commission (CPUC) Energy Division (ED). The sample of customers included 150,000 accounts, randomly assigned to one of two equal-sized groups: program participants (treatment or T group) and comparison group (control or C group). The sample was stratified by energy use, with a higher proportion of relatively high electricity use customers included, but also included users of all levels. There were some problems with mismatching of addresses prior to the first 2014 mailing that led to some treatment customers not receiving their HER reports. AEG addressed this situation in both Opower-2 PY 2014 and 2015 in a way consistent with CPUC guidance in estimating the program savings and approval of the 2014 Opower-2 methodology.[2]

Scope of This Savings Assessment

This report describes the implementation of the 2015 program, explains our analysis methods, presents detailed energy savings results, and discusses our findings. Our evaluation employed two statistical methodologies to provide ex-post estimates of the HER program savings: We conducted difference in differences analyses to gauge overall energy savings and peak load

[1] The last reports from Opower-2 were sent out in December 2014, which means there was a slightly longer than usual gap between reports in 2014 and 2015.

[2] Validation of the sample and full evaluation results from Opower-2 are presented in "SCE's Home Energy Report Program Savings Assessment: Ex-Post Evaluation Results, Program Year 2014," prepared by Applied Energy Group, CALMAC ID SCE0391.01 http://calmac.org/publications/SCE_2014_HER_Evaluation_Report_FINAL_Oct_2015.pdf

impacts achieved during the pilot. Then we used regression modeling to refine the energy savings estimate.

The goal was to provide ex-post estimates of savings for the period January-December 2015 that are attributable to the HER program, including:

- kWh savings achieved by the program participants, minus their savings claimed by other SCE programs operating during that time
- Peak kW savings calculated two ways, applying a load factor to participants' kWh savings based on SCE's load research data and direct estimation from hourly interval data, minus their kW savings claimed by other SCE programs operating during that time

Report Organization

The report is organized as follows:

- Chapter 2 describes the energy savings analysis methods, including the approaches we followed for the difference in differences analysis and the regression modeling.
- Chapter 3 presents results from the kWh savings analysis across the program year.
- Chapter 4 describes the methods and results of estimating the peak kW savings.
- Chapter 5 discusses the attribution of savings to the HER and SCE's downstream energy efficiency programs.
- Chapter 6 discusses the method of attributing savings to the HER and SCE's upstream lighting program.
- Chapter 7 summarizes the findings from our analysis.

Chapter 2 – Analysis Methods for Energy Savings

Overall Analysis Approach

To provide an independent estimate of kWh savings from this program, we used two statistical methods: difference in differences and regression analysis. Both make use of pre-treatment and post-treatment monthly billing data for the treatment and control customers that were randomly assigned from the program population at the start of the program, with the mismatched address customers all retained, as described above. First, we used a difference in differences method, which directly estimates the energy savings for each month, along with a standard error and confidence intervals for those savings. Then we refined that direct estimate with a fixed-effects regression model, which also incorporates actual weather data for that same period and reduces variance by accounting for different average energy use across the customers.

Both of these methods provide savings estimates by month along with the associated confidence intervals. The direct estimate from the difference in differences method provides an initial estimate of savings for each month that is not affected by the assumptions of a regression model. Because the regression model includes assumptions about the structure of the data and the nature of the residuals, it helps to have a preliminary estimate to compare with. If the regression model results are comparable to the initial estimates, we can be more confident that the results are valid. Because the regression model incorporates weather and reduces variance by using customer-specific fixed-effects, it will generally provide a more precise estimate than the direct estimate. It also has the advantage that the model can be used to estimate what the savings would have been under different weather scenarios, though estimation of impacts under alternative weather scenarios is not in the scope of this project.

Difference in Differences

Equation (1) shows the mathematical calculations used in the difference in differences (DID) analysis to estimate energy savings for each month. In this case, the “before” refers to the pre-treatment month, and the control group is the group that did not receive a report.

$$\text{Savings} = (\text{Cntl}_{\text{after}}\text{-}\text{Tx}_{\text{after}})\text{-}(\text{Cntl}_{\text{before}}\text{-}\text{Tx}_{\text{before}}) \qquad (1)$$

Where

$\text{Cntl}_{\text{after}}$ is the average control group customer energy use in the treatment (after) period

Tx_{after} is the average participant group (also referred to as the treatment group) customer energy use in the treatment (after) period

$\text{Cntl}_{\text{before}}$ is the average control group customer energy use in the pre-treatment (before) period

$\text{Tx}_{\text{before}}$ is the average participant group customer energy use in the pre-treatment (before) period

We also calculated standard errors and confidence intervals using the appropriate statistical formulas for the difference of two random variables (estimates).

The DID provides an initial estimate of savings for each month. We did not eliminate the data for opt-out or mismatched address customers from the dataset. The number of customers that opted out was small, the effect of excluding them would have been small, and excluding them could have corrupted the randomization from the experimental design. We also included those customers when expanding the average customer results to the total population, so they were treated consistently.

Regression Modeling

We next estimated savings using a fixed-effect regression model. Both treatment and control customers are included in the model, which includes variables related to participation and weather. The model also includes a fixed effect for each customer, which is a customer-specific intercept.

The fixed-effects regression approach controls for unmeasured differences between customers that are constant over time, such as home size, vintage, major appliances, and household size, allowing us to better isolate and estimate the energy use changes associated with program participation (the savings) more precisely. We use a standard fixed-effects (also known as panel) regression, and use robust errors to reflect the correlation of the errors in the model.

The independent variables incorporated are as follows:

- Temperature (cooling degree days and heating degree days)
- Treatment period year and month – to account for any changes in customer energy use over time that is *not* related to the program
- Participation (non-zero only for treatment customers during the treatment period)

The model looks at the dependent variable (monthly energy use) as a function of the other independent or explanatory variables and then estimates the coefficients of the variables in that function.

Equation (2) below is the model specification we used. This specification is fully consistent with guidance contained in the SEE Action report on behavior program evaluation.[3]

[3] Specifically, the model utilizes specification 1.4 in Appendix C: Overview of Acceptable Model Specifications in State and Local Energy Efficiency Action Network. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations*. Prepared by A. Todd, E. Stuart, S. Schiller, and C. Goldman, Lawrence Berkeley National Laboratory. http://behavioranalytics.lbl.gov.

$$kwh_{it} = \alpha_i + [\gamma_{1t} + \gamma_{2t}P(x)]Month_t + [\gamma_{3t} + \gamma_{4t}P(x)]CDD_t + \beta_t P(x)T(x)Month_t + \varepsilon_{it} \quad (2)$$

Where the variables and their coefficients are defined as:

kwh_{it}	Consumption of customer i in month t
α_i	A fixed effect for each customer i
$[\gamma_{1t} + \gamma_{2t}P(x)]Month_t$	A vector of monthly indicator variables where $P(x)$ is an indicator variable that takes on a value of one during the treatment period
$[\gamma_{3t} + \gamma_{4t}P(x)]CDD_t$	The cooling effect of month t where $P(x)$is an indicator variable that takes on a value of one during the treatment period
$\beta_t P(x)T(x)Month_t$	A vector of monthly indicator variables where $P(x)$ is an indicator variable that takes on a value of one during the treatment period and $T(x)$ is an indicator variable that takes on a value of one if a customer i is a program participant
ε_{it}	The error for customer i during month t

Appendix A contains the output of the final regression model.

Data Used in Analysis

We conducted the energy analysis using monthly energy data for the pre-treatment and treatment periods. We used monthly billing data for the period of March 2013 through December 2015. The treatment period began on March 18, 2014, when the first HER reports were sent out. We included January and February 2014 bills in the pretreatment period along with any bills that ended prior to March18th, when the first mailing was sent. All subsequent bills were considered to be a part of the treatment period.

Since this evaluation is for the second year of this particular Opower program, there were a couple of options for the regression modeling. One choice was to include data for only the pre-treatment period (March 2013 through February 2014) and the treatment year we were analyzing (January-December 2015). The other option was to include the entire span of data from March 2013 through the end of the treatment year, December 2015. We tried both methods and the results for 2015 were similar. However, our final estimates are based on the model including all the available data, with the impacts for each month estimated separately. This approach provides more stability in the estimation of the parameters, since there is more data going into the model. It should particularly help the estimation of the baselines, including both the monthly baseline coefficients and especially the CDD coefficients.

When we calculated the savings estimates and their statistical significance, all the months in 2015 were statistically significant in both the difference in differences and in the regression models, so all were included in the savings calculations.

For participants and control group customers who moved out of their homes during the treatment period, we included energy data up until the time they left.

Table 1 illustrates the customer attrition due to customers who moved out during the treatment period of the study. The table shows the count of households that had available data for the treatment and control groups by month. The number of closed accounts is tracked by month and cumulatively. For completeness sake, we include the information from the 2014 program year as well as 2015.

Table 1. Customer Account Attrition

Month	Control Group			Treatment Group		
	Open Accounts[a]	Closed Accounts		Open Accounts[a]	Closed Accounts	
		Monthly	Cumulative		Monthly	Cumulative
Mar 2014	73,881	1,119	1,119	73,786	1,214	1,214
Apr 2014	73,551	330	1,449	73,472	314	1,528
May 2014	73,265	286	1,735	73,169	303	1,831
Jun 2014	72,915	350	2,085	72,848	321	2,152
Jul 2014	72,489	426	2,511	72,428	420	2,572
Aug 2014	72,118	371	2,882	72,088	340	2,912
Sep 2014	71,795	323	3,205	71,784	304	3,216
Oct 2014	71,384	411	3,616	71,415	369	3,585
Nov 2014	71,076	308	3,924	71,138	277	3,862
Dec 2014	70,793	283	4,207	70,833	305	4,167
Jan 2015	70,555	238	4,445	70,537	296	4,463
Feb 2015	70,304	251	4,696	70,296	241	4,704
Mar 2015	70,069	235	4,931	70,047	249	4,953
Apr 2015	69,719	350	5,281	69,701	346	5,299
May 2015	69,403	316	5,597	69,400	301	5,600
Jun 2015	69,066	337	5,934	69,069	331	5,931
Jul 2015	68,719	347	6,281	68,705	364	6,295
Aug 2015	68,378	341	6,622	68,356	349	6,644
Sep 2015	68,022	356	6,978	67,963	393	7,037
Oct 2015	67,697	325	7,303	67,657	306	7,343
Nov 2015	67,418	279	7,582	67,357	300	7,643
Dec 2015	67,139	279	7,861	67,101	256	7,899

[a] Count of number of customer accounts varies by month due to account closure.

Chapter 3 – Energy Savings Results

Difference in Differences Results (Initial kWh Savings Estimates)

Table 2 summarizes the per-participant energy impacts estimated with the difference in differences (DID) approach for all program participants from January 2015 through December 2015. The table includes the number of participants included in the analysis month, average per-participant adjusted control group (baseline) billing energy use, and average per-participant estimated energy savings in kWh and the percentage savings. The table also indicates whether or not the savings estimates are statistically significant based on 90% confidence for each month.

Table 2. Monthly Ex-Post Energy Savings Estimates: Difference in Differences

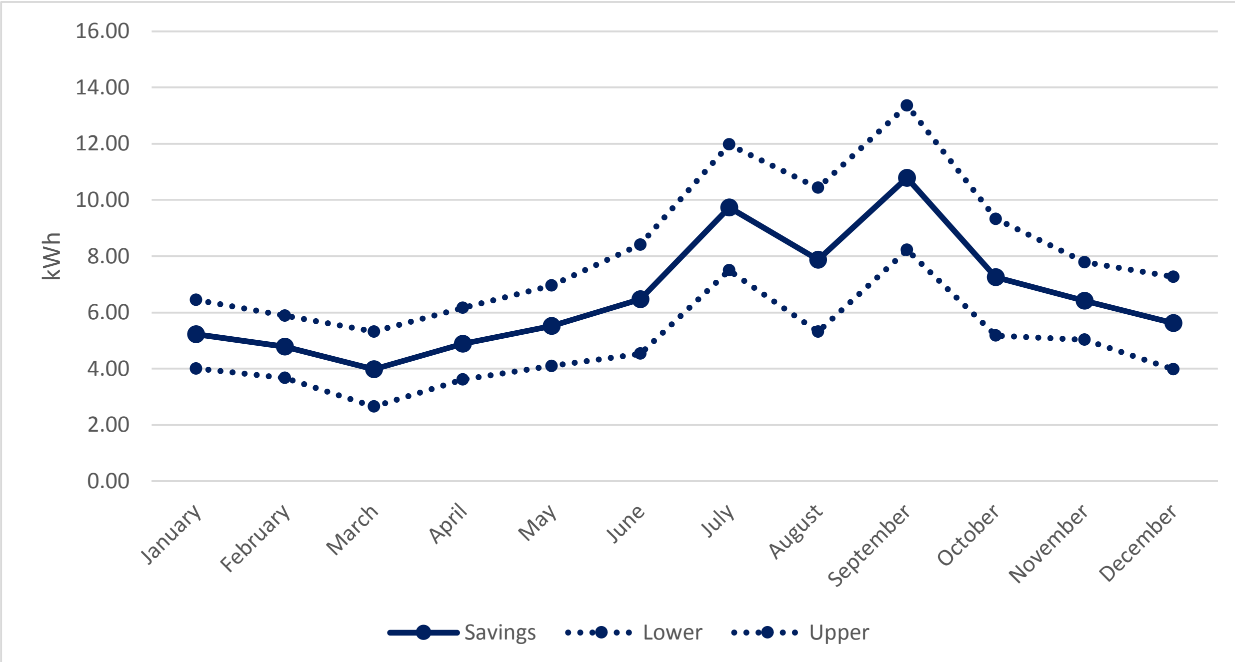
Month	Average Adjusted Control Group Billing Energy (kWh)	Average Estimated Per-Participant Savings (kWh) [a]	% Savings	Significant?
Jan 2015	548.11	5.23	0.95%	Yes
Feb 2015	494.39	4.78	0.97%	Yes
Mar 2015	516.30	3.99	0.77%	Yes
Apr 2015	500.72	4.89	0.98%	Yes
May 2015	500.77	5.53	1.10%	Yes
Jun 2015	652.01	6.47	0.99%	Yes
Jul 2015	783.23	9.74	1.24%	Yes
Aug 2015	909.00	7.87	0.87%	Yes
Sep 2015	940.93	10.79	1.15%	Yes
Oct 2015	746.43	7.25	0.97%	Yes
Nov 2015	525.68	6.41	1.22%	Yes
Dec 2015	588.21	5.62	0.96%	Yes
Total	7,705.79	**78.58**	**1.02%**	

[a] Savings differences due to rounding of average per-participant displayed values

The table shows that the statistically significant per-participant savings range from a minimum of 0.77% in March 2015 to a maximum of 1.24% in July 2015. Overall, the analysis indicates an average savings across the program of about 1.0%. While there are fluctuations between months, the savings are generally flat across the program year on a percentage basis. On a kWh basis, the highest savings occur during the summer months, when the energy use is highest.

Figure 1 plots the average per-participant energy results based on the difference in differences results. It shows the monthly energy savings and 90% confidence intervals. In all cases, the lower bounds of the confidence intervals are above zero, indicating that the savings are statistically significant.

Figure 1. Difference in Differences Average Per-Participant 2015 Monthly Energy Savings Estimates



Regression Analysis (Final kWh Savings Estimates)

After estimating the savings using a difference in differences, we then estimated the savings using a fixed-effects regression model. The first step in the assessment of the regression model was to check the results for consistency against the results from the difference in differences analysis. We found that the results were similar and, as expected, the results of from the regression model are somewhat more precise. We used the regression model results to make the final program-level estimates presented at the end of this chapter.

Table 3 summarizes the average per-participant monthly energy savings estimated with the regression model approach for the treatment period of January 2015 to December 2015. The table includes the average baseline energy use during the treatment period, the estimated treatment customer average energy savings, and the percent energy savings. The table also indicates whether or not the regression model savings estimates are statistically significant for the given month.

The table shows the per-participant monthly savings, an average of 6.5 kWh per month over the entire year and 77.74 for the entire year. Percentagewise, the monthly savings range from a minimum of 0.8% in March to a maximum of 1.3% in November. Overall, the analysis yields an average savings across the treatment period of 1.02%, identical to the annual result for the DID analysis. The magnitudes of these results are similar to the DID results. There is an unexpected bump in the savings in September for the DID analysis, which is not present in the regression results, but overall the results are similar. Like the difference in differences estimates, the regression estimates are statistically significant throughout the analysis period.

Table 3. Monthly Ex-Post Energy Savings Estimates: Regression Analysis

Month	Average Regression Estimated Baseline Billing Energy (kWh)	Average Estimated Savings (kWh) [a]	% Savings	Significant?
Jan 2015	547.99	4.90	0.89%	Yes
Feb 2015	495.07	4.30	0.87%	Yes
Mar 2015	516.04	4.14	0.80%	Yes
Apr 2015	500.47	5.34	1.07%	Yes
May 2015	500.46	5.95	1.19%	Yes
Jun 2015	651.45	7.91	1.21%	Yes
Jul 2015	782.20	9.48	1.21%	Yes
Aug 2015	907.77	8.61	0.95%	Yes
Sep 2015	939.85	7.80	0.83%	Yes
Oct 2015	745.61	6.77	0.91%	Yes
Nov 2015	525.18	6.71	1.28%	Yes
Dec 2015	587.77	5.82	0.99%	Yes
Total	7,699.86	**77.74**	**1.02%**	

[a] Total savings differences due to rounding of average per-participant displayed values

Figure 2 and Figure 3 plot the average per-participant monthly energy savings based on the final regression analysis. The first figure readily shows the kWh savings across months, underscoring seasonality of the kWh savings. The second figure shows the monthly energy savings and 90% confidence intervals. In all cases, the lower bounds of the confidence intervals are above zero, indicating that the savings are all statistically significant.

Figure 2. Regression Analysis, Average Monthly kWh Savings Per-Participant in 2015

Figure 3. Regression Analysis Average Per-Participant kWh Savings 90% Confidence Bounds

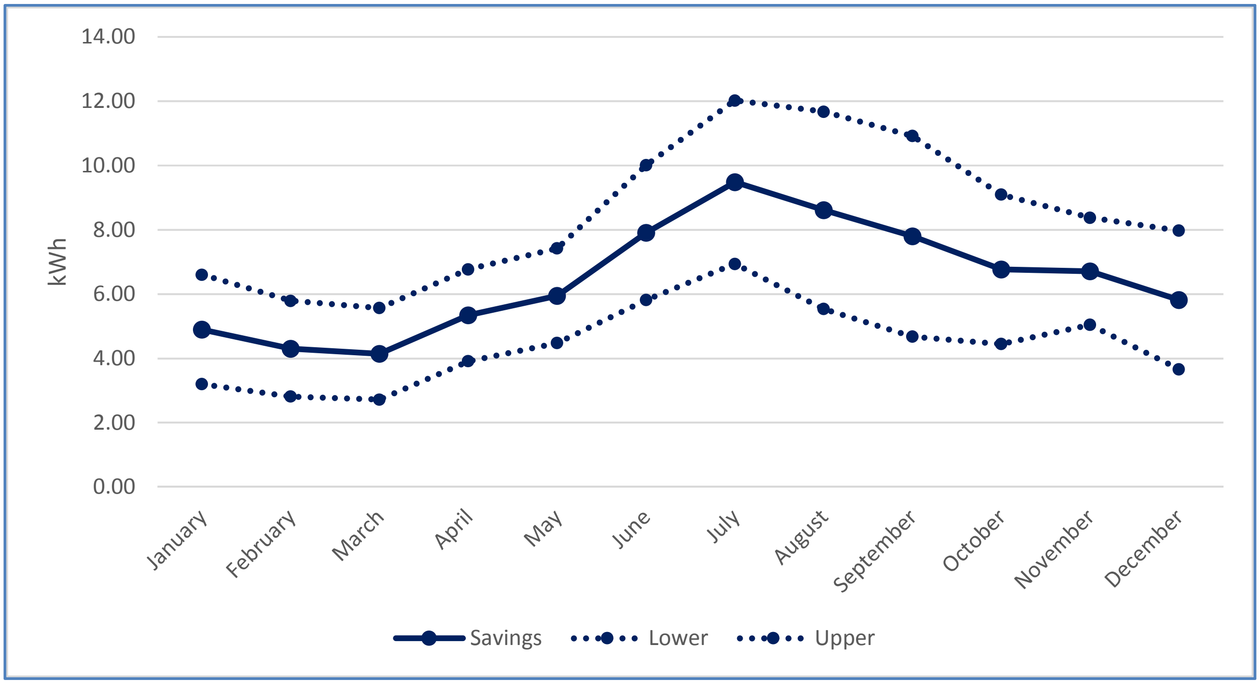


Figure 4 compares the monthly energy savings estimated with the regression model and the difference in differences approach. The energy savings are very similar across the whole treatment period, with the exception of September, which shows more difference than any other month. However, the total savings estimates for the treatment period differ by less than 1 kWh per participant.

Figure 4. Average Per-Participant kWh Savings Estimates: Comparison of Regression and Difference in Differences Results

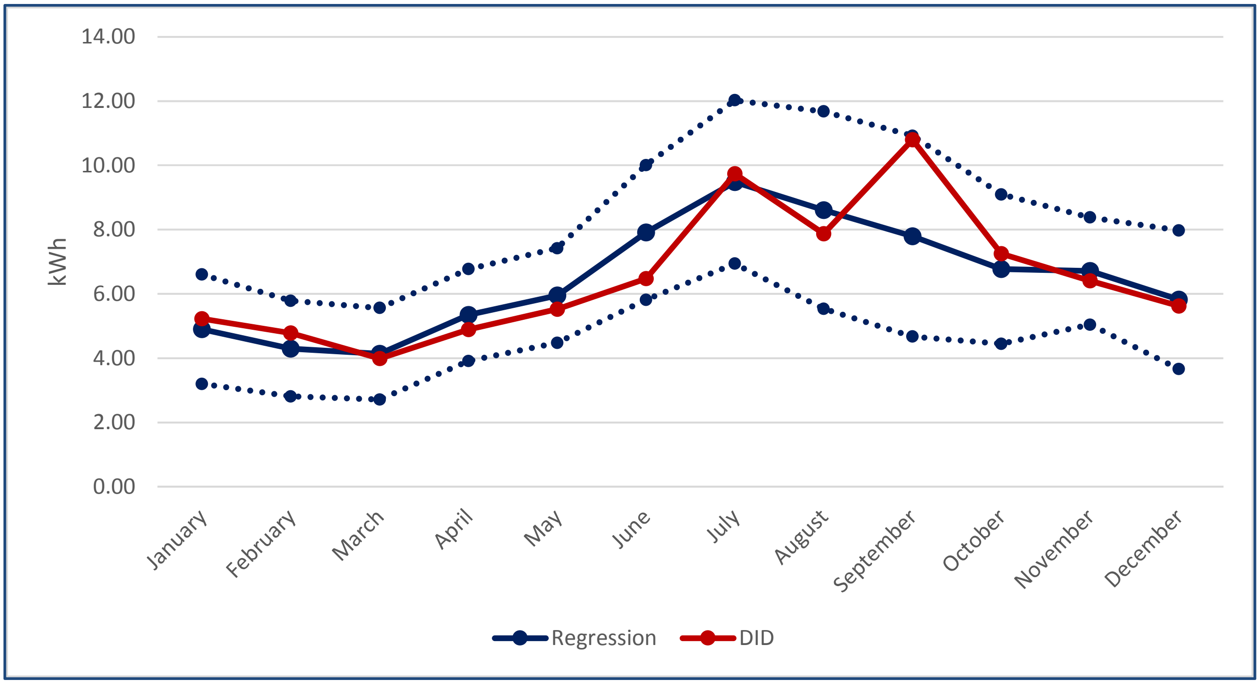
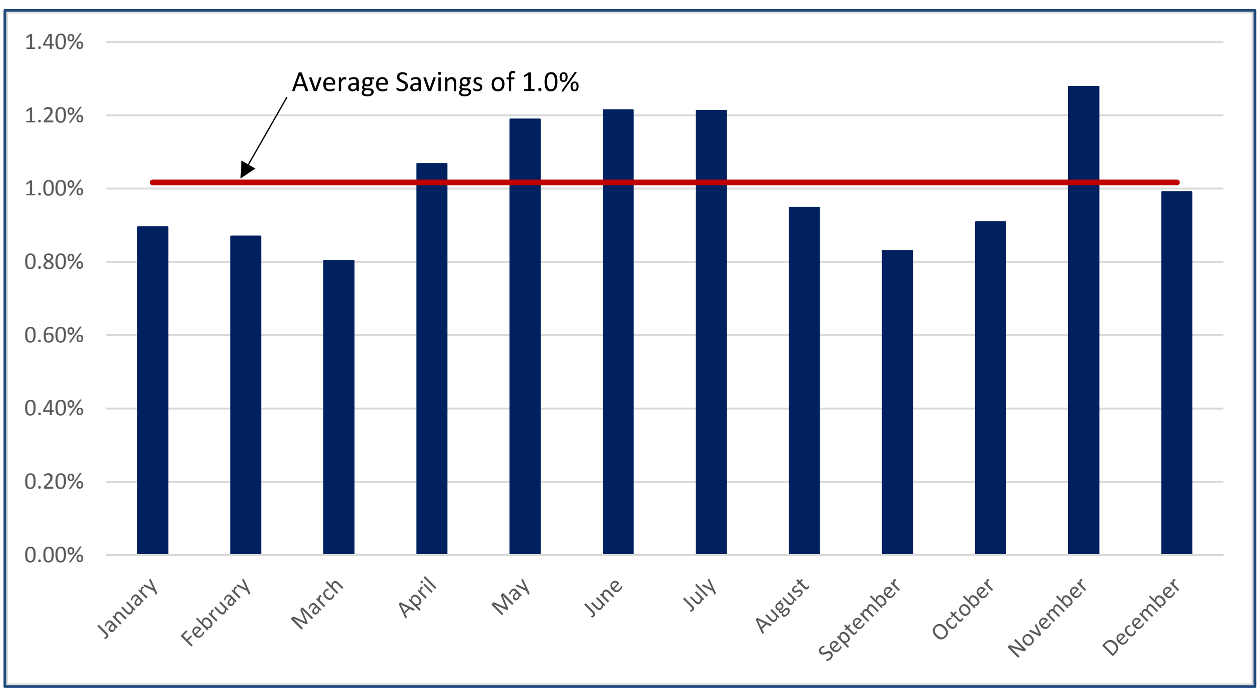


Figure 5 shows the monthly percentage savings estimates from the regression model across the entire treatment period. It also plots the average annual percentage energy savings achieved through the 12 months of the 2015 program based on the regression results (1.0%).

Figure 5. Monthly kWh Savings Estimates: Percentage Savings, from Final Regression Model



Program-Level Savings

The results from both the difference in differences model and the regression model show similar savings estimates. Because they are more precise, we used the regression model results to calculate program-level savings.

Table 4 presents the total HER program savings before the adjustment for incremental upstream and downstream program savings discussed in Chapters 5 and 6. We calculated the HER program-level savings by multiplying the average per-participant savings from the regression model by the number of active treatment accounts in each month. This gave us a total of 5.34 GWh of savings, before adjusting for the savings from other programs.

The number of active accounts is decreasing each month during the treatment period due to customer attrition, or move-outs. Again, we did not exclude the opt-out or mismatched address customers from this calculation. There was an average of 68,849 program participants, which was calculated by taking the average number of monthly participants during the 12 months of the treatment period.

Table 4. Total HER Program Energy Savings (before adjustment for other program savings)

Month	Participants [a]	Average Per-Participant Savings (kWh) [b]	Total Savings (kWh) [b]
Jan 2015	70,537	4.90	345,741
Feb 2015	70,296	4.30	302,422
Mar 2015	70,047	4.14	290,149
Apr 2015	69,701	5.34	372,460
May 2015	69,400	5.95	412,854
Jun 2015	69,069	7.91	546,319
Jul 2015	68,705	9.48	651,310
Aug 2015	68,356	8.61	588,359
Sep 2015	67,963	7.80	529,919
Oct 2015	67,657	6.77	458,189
Nov 2015	67,357	6.71	452,016
Dec 2015	67,101	5.82	390,559
Total [b]	**68,849**	**77.74**	**5,340,297**

[a] Average monthly customers

[b] Total differences due to rounding of displayed values

Chapter 4 – Peak Demand Impacts

We conducted analyses using two different methods to assess the peak kW impacts of the Opower-2 PY 2015 program. We used the 3-day heat wave as defined by DEER for both estimates. We made one estimate by simply applying an average residential class load factor to the estimated kWh savings from the regression analysis. We also developed an estimate from a difference in differences analysis using interval data from the actual participants.

One of the ancillary objectives of this analysis was to assess the two alternative methods of estimating peak kW savings. The question is: do the Load Factor (LF) approach and Interval Data approach consistently yield sufficiently close results to instill confidence in the lower cost method? The LF approach costs considerably less to implement since it does not require the assembly and analysis of very large advanced metering infrastructure (AMI) interval data files. The key difference between the two methods is that the LF method assumes no change in the load shape—i.e., the savings are proportionally distributed across all hours, while the Interval Data approach allows the savings to vary freely across hours of the day. For both analyses of the Opower-2 participants (2014 and 2015), we found that the LF approach produced peak load savings notably higher than the Interval Data approach. So for PY 2015, we do not believe that the less expensive load factor method is sufficient, and we use the interval data approach for the final savings estimate. Since the LF approach adds very little cost to the ex-post evaluation, however, we encourage continuation of both methods for a few more program years before drawing a final conclusion.

The savings estimate from the interval data analysis represents our final result of peak load savings for the Opower-2 PY 2015 program. We include documentation of the results using both methods below.

Load Factor Approach

Once we estimated the kWh savings, we then calculated a preliminary estimate of kW savings using SCE's Dynamic Load Profiles (DLP), reweighted to better reflect the makeup of the Opower-2 population. We used these load profiles to develop a load factor for the peak hours, which we then applied to the kWh savings to obtain a rough estimate of the kW savings.

The SCE's dynamic load profiles are based on a stratified sample representing the entire SCE residential population, with stratification based on average monthly energy use, climate zone, and housing type (single family and multifamily). We calculated new weights based on the distribution of customers in the Opower-2 population across the strata defined by the DLP sample, as of the time of the 2015 peak. By applying these alternative weights to the DLP sample interval data, SCE's Load Research department recalculated an annual 8,760-hour load shape that reflected the customers in the Opower-2 participant population.

Using this reweighted 8,760-hour load shape and the 2015 DEER-defined 3-day heat wave, which was September 8-10, 2015 for the climate zones included in the participant population[4], we calculated the average kW for the three peak hours from 2:00-5:00 PM on each of the three days. Using that average peak kW, we calculated the peak load factor as the ratio of the annual consumption to the product of the peak demand and the number of hours (8,760). The peak load factor based on the reweighted dynamic load profile using this approach was 37.78%.

We then applied that load factor to the annual savings estimate from the regression analysis, with the incremental savings removed to get the preliminary kW savings estimate of 1,379 kW.

$$(Preliminary)\ Peak\ Demand\ Savings_{LF} = 1{,}614kW = \frac{4{,}565{,}344\ kWh}{(0.3778\ \times 365 \times 24)}$$

Next, we discuss the improved savings estimate of the peak demand impacts using actual interval data.

Interval Data Approach

We developed a kW savings estimate based on the actual treatment and control group customer interval data using a difference in differences method to give an estimate that more directly represents the savings for these customers. SCE provided hourly interval data for the summer months between 2013 and 2015 for both treatment and control group customers.

We validated and cleaned the 2013 and 2015 interval data by checking for missing values, zeroes, negatives, and outliers. In a given day, if there were more than three missing hours or more than three zeroes, we considered it an unusable day of data for that account. In addition, if a day had more than one negative hourly value, we flagged the day as unusable.[5] We used two separate processes to identify outliers. First, for each summer day type,[6] we calculated average daily energy and the associated standard deviation. Days that were more than four standard deviations away from the season and day type mean (in either direction) were considered unusable. The second approach to identifying outliers was to examine the maximum daily kW and compare it to the preceding day's value. We excluded records if the current day's value was more than six times larger than or less than 1/6th the size of the previous day's max. Finally, we omitted customers with more than 20% of their days flagged as unusable. Overall, the SCE data were quite clean. In total, the exclusions from the cleaning amounted to just under 1% of the records.

Initially, we estimated the kW savings based the interval data the same way we have in the past, using a simple average of the peak demand values for the treatment and control groups during the pre-treatment and treatment periods. For this 2015 program, this estimate was not statistically significant. Looking at the data, we discovered that there was a higher rate of missing or erroneous interval data for the larger customers. This meant that these simple

[4] When we did this calculation, the heat wave fell on these same three days for 99.9% of the participants. So we used September 8-10, 2015 for all the accounts.

[5] We found only two negative values throughout the entire dataset and assigned them a missing value.

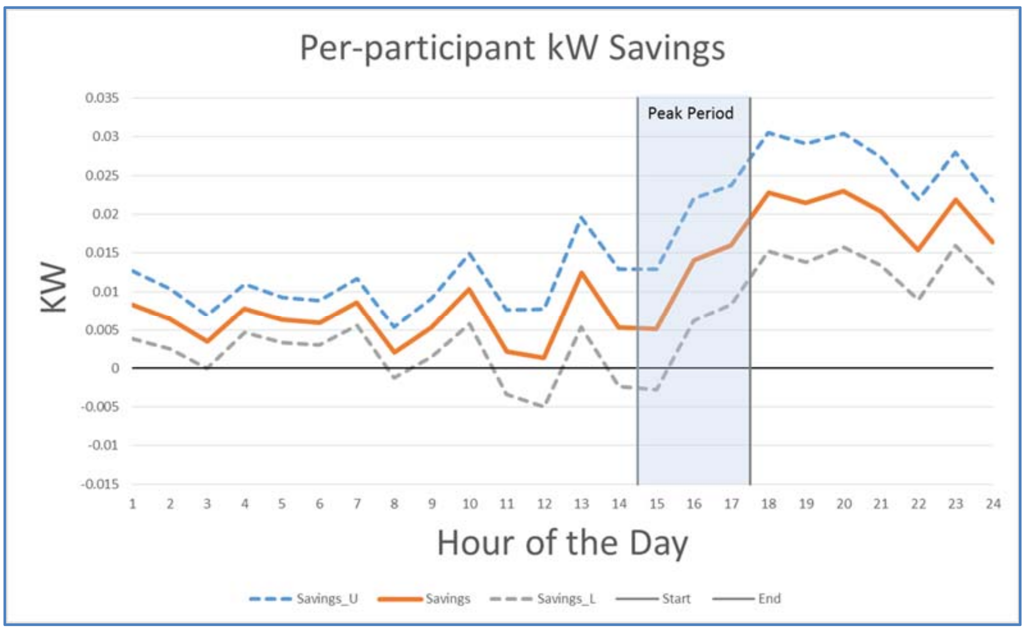
[6] Weekday versus weekend.

averages were too low, since they represented a biased estimate of energy use for the treatment and control group because of the unequal rates of data exclusion. To correct for this, and to give a more precise estimate of savings, we used a stratified estimator for the averages, using the three strata defined during the sample design for this Opower program. Using the original stratum assignments, we calculated weights reflecting the proportion of customers in each stratum that were still active as of the 2015 heat wave (September 8-10, 2015). These weights were then applied to the stratum average values for the customers with good data, thereby correcting for the different rates of data loss. Because the population was stratified based on energy use, this also increased the precision of these estimates, which then led to a more precise estimate of savings. The kW savings result, using the stratified estimators, was statistically significant. The estimates in the remainder of this report are based on this stratified estimate of savings.

For the interval data approach, the resulting average per-participant peak savings is 0.012 kW. This is a savings of 0.43% from baseline demand. The 90% confidence interval is +/- 0.007 kW.

Figure 6 shows the per-participant savings across all hours of the day during the heat wave, with the DEER-defined peak period hours highlighted. Only these three peak period hours were used to calculate the program savings. We note that the highest demand savings actually occur after the DEER-defined peak hours.

Figure 6. Interval Data Peak kW Savings Per-Participant in 2015



Finally, we calculated the aggregate (program-level) kW impact. We did this by taking the average per-participant savings estimate and multiplying it by the number of participants as of September 8, 2015, which was 67,903. Thus, the interval data approach yields a kW impact estimate of 800 kW. To calculate the final peak demand savings estimate, we removed the savings associated with and already counted in other programs, 40.6 kW from downstream and 29.6 kW from upstream programs, to avoid double counting.[7]

$$(Final\ Direct)\ Peak\ Demand\ Savings_{ID} = 799.61\ kW - \ downstream\ \ - upstream$$
$$= \ (0.01178\ kW \times 67{,}903) - 40.6\ kW - 29.6\ kW$$

The result from the analysis of interval data, 800 kW, is our final estimate of the kW savings associated with the Opower-2 PY 2015 program, before removal of the incremental savings already counted in SCE's other programs.

[7] Details of the upstream and downstream incremental savings are in Chapters 5 and 6.

Chapter 5 – Attributing Savings to Downstream Programs

SCE provided AEG with the annual per-measure net savings estimates for HER participant and control group customers' participation in other energy efficiency programs the company offered in 2015, from the savings data submitted to CPUC. These programs are referred to as downstream programs because incentives are offered directly to the end-users of energy and their participation and expected savings are tracked by individual households.

A wide range of energy efficiency measures are rebated through these programs. Because SCE receives credit for the savings achieved through these programs, it is possible that part of the total 2015 HER savings estimated and reported in the previous chapters are attributable to and were counted as part of those downstream programs' savings. Note that it is only the incremental difference in savings between the treatment and control group customers that are at risk of double counting – the control group accounts form a "baseline" level of participation that would have happened in the absence of the Opower-2 program.

This is the second year of treatment for participants in the Opower-2 wave. This means that there are two components to the downstream incremental savings calculations:

- First-year incremental savings from installations made during the 2015 program year
- Second-year incremental savings from installations made during the 2014 program year

The savings from both of the components combined are removed from the total Opower-2 PY 2015. In this chapter we show calculation of the savings from each of the two components individually and their combined impact.

2015 Installations

Table 5 shows the kWh savings attributed to the 2015 downstream programs for the Opower-2 customers that installed a measure in 2015 and the incremental difference between those who received a HER and those who didn't. We calculated the kWh difference by prorating the annual kWh for each measure to the number of days in the treatment period after that measure was installed in 2015. Next, we subtracted the prorated kWh savings of the control customers from that of the treatment group to get the incremental savings during the treatment period.

Table 5. Downstream Program Savings from Installations Made in 2015 (kWh)

Measure	Control		Treatment		kWh Difference
	Customer Measure Count	kWh Savings [a]	Customer Measure Count	kWh Savings [a]	
Central AC	44	15,107.39	59	17,546.20	2,438.81
Evap Cooler	5	328.57	8	758.59	430.01
Lighting	10	365.74	12	362.89	(2.85)
In Home Survey	0	0.00	1	108.64	108.64
Mail Survey	2,387	222,381.30	2,377	22,2818.24	436.95
Online Survey	2	318.66	1	80.80	(237.86)
Phone Survey	1	200.73	3	494.92	294.19
Pool Pump	120	54,007.73	128	52,448.38	(1,559.35)
Refrigerator	1,247	413,569.35	1,455	505,176.78	91,607.43
Whole House Retrofit	65	39,753.35	58	40,564.56	811.21
Whole House Fan	1	(4.57)	1	(4.57)	0.00
Attic Insulation	56	4,452.79	46	2,400.19	(2,052.60)
Clothes Washer	98	16,871.63	85	14,377.84	(2,493.79)
Heat Pump	1	261.97	0	0.00	(261.97)
Room AC	0	0.00	1	17.97	17.97
Total	**4,037**	**767,614.66**	**4,235**	**857,151.44**	
	Total Difference in Savings (kWh)				**89,536.78**

[a] Total savings differences due to rounding of average per-measure displayed values

Table 6 shows the analogous information for the kW savings associated with the downstream programs. AEG calculated the kW difference by including the measures and kW savings for only those customers in each group who had installed their measures by September 08, 2015, the first day of the 2015 heat wave period. The Customer Measure Count in Table 6 is different from Table 5 shows the kWh savings attributed to the 2015 downstream programs for the Opower-2 customers that installed a measure in 2015 and the incremental difference between those who received a HER and those who didn't. We calculated the kWh difference by prorating the annual kWh for each measure to the number of days in the treatment period after that measure was installed in 2015. Next, we subtracted the prorated kWh savings of the control customers from that of the treatment group to get the incremental savings during the treatment period.

Table 5 due to the fact that certain measures are only attributed to peak savings (kW) as opposed to overall savings (kWh). The individual kW values for each customer with peak day installations were not prorated since they reflect the demand savings on the peak day.

Table 6. Downstream Program Savings from Installations Made in 2015 (kW)

Measure	Control		Treatment		kW Difference
	Customer Measure Count [a]	kW Savings [b]	Customer Measure Count [a]	kW Savings [b]	
Central AC	40	10.83	52	15.02	4.19
Evap Cooler	0	0.00	1	0.73	0.73
Lighting	7	0.06	9	0.07	0.01
In Home Survey	0	0.00	1	0.07	0.07
Mail Survey	2038	207.88	2037	207.77	(0.10)
Online Survey	0	0.00	0	0.00	0.00
Phone Survey	1	0.06	2	0.12	0.06
Pool Pump	92	15.04	109	11.19	(3.85)
Refrigerator	967	119.32	1191	145.84	26.52
Whole House Retrofit	57	72.68	55	74.97	2.28
Whole House Fan	1	0.00	1	0.00	0.00
Attic Insulation	56	4.32	46	2.33	(1.99)
Clothes Washer	98	4.53	85	4.37	(0.15)
Heat Pump	1	0.15	0	0.00	(0.15)
Room AC	0	0.00	1	0.06	0.06
Total	**3,358**	**434.87**	**3,590**	**462.54**	
	Total Difference in Savings (kW)				**27.66**

[a] Reflects measures installed by September 8, 2015

[b] Total savings difference due to rounding of average per-participant displayed values

During the 2015 treatment year, a total of 4,037 energy efficiency measures were installed by customers assigned to the control group, 3,358 of them by September 08, 2015. The total prorated savings achieved by the control group through downstream measures for the 2015 installments was 767,615 kWh and 434.87 kW. This is compared to a total of 4,235 energy efficiency measures installed by customers who received HER reports, 3,590 of them by September 08. The total prorated downstream savings from the treatment group for that period was 857,151 kWh and 462.54 kW. The difference between the two groups, the incremental savings resulting from HER that would be counted elsewhere, are 89,537 kWh and 27.66 kW.

2014 Installations- Second Year Effects

In addition to the 2015 measures attributed to the downstream programs, there are also measures that were installed by Opower-2 participants during the 2014 program year that have a rollover savings effect in 2015. For this, SCE also provided AEG with the annual per-measure net savings estimates for HER participant and control group customers' participation in other energy efficiency programs the company offered in 2014, from the savings data submitted to CPUC. In addition, SCE provided the total savings over the measure's lifetime so the savings from the 2014 measures could be applied to the 2015 year.

Table 7 shows the kWh savings in 2015 for the Opower-2 customers that installed a downstream measure in 2014 as well as the incremental difference between the customers who received a HER and those who didn't. For customers who continued to have active accounts throughout 2015, we used the entire full year kWh savings in the calculations. For those who became inactive during 2015, we calculated the kWh difference by prorating the annual kWh for each measure to the number of days they had an active account in 2015. Only customers who installed a downstream measure after the start of the Opower-2 wave in March 2014 and were active during the 2015 year were included in the savings calculations. Only 87 of the treatment and control accounts active during PY 2014 became inactive in 2015. Next, we subtracted the the kWh savings of the control customers from that of the treatment group to get the second-year incremental savings during the 2015 program year.

Table 7. Downstream Program Rollover Savings from Installations Made in 2014 (kWh)

Measure	Control		Treatment		kWh Difference
	Customer Measure Count	kWh Savings [a]	Customer Measure Count	kWh Savings [a]	
Central AC	65	28,670.48	50	20,783.52	(7,886.96)
Lighting	146	15,448.50	213	20,028.51	4,580.01
In Home Survey	1	314.70	0	-	(314.70)
Mail Survey	2072	434,622.30	2032	426,257.65	(8,364.65)
Online Survey	2	73.40	2	73.40	-
Phone Survey	1	281.83	3	618.48	336.65
Pool Pump	53	33,955.41	82	46,214.34	12,258.93
Refrigerator	889	498,520.79	1000	569,809.99	71,289.20
Whole House Retrofit	20	28,390.63	25	37,090.75	8,700.12
Whole House Fan	16	127.10	18	80.33	(46.77)
Total	**3,265**	**1,040,405.15**	**3,425**	**1,120,956.97**	
	Total Difference in Savings (kWh)				**80,551.82**

[a] Total savings differences due to rounding of average per-measure displayed values

Table 8 shows the analogous information for the kW savings associated with the downstream programs. AEG calculated the kW difference by including the measures and kW savings for only those customers in each group who had installed their measures by September 08, 2015, the first day of the 2015 heat wave period. That is why the kW customer counts are different from Table 7. The individual kW values for each customer with peak day installations were not prorated since they reflect the demand savings on the peak day.

Table 8. Downstream Program Rollover Savings from Installations Made in 2014 (kW)

Measure	Control		Treatment		kWh Difference
	Customer Measure Count	kW Savings [a]	Customer Measure Count	kW Savings [a]	
Central AC	39	5.31	26	3.45	(1.87)
Lighting	135	2.81	210	3.67	0.86
In Home Survey	0	-	0	-	-
Mail Survey	1310	133.62	1282	130.76	(2.86)
Online Survey	0	-	0	-	-
Phone Survey	1	0.06	2	0.12	0.06
Pool Pump	41	2.88	65	3.70	0.82
Refrigerator	497	49.51	537	55.77	6.26
Whole House Retrofit	14	34.31	19	43.98	9.67
Whole House Fan	14	0.04	15	0.04	0.00
Total	**2,051**	**228.55**	**2,156**	**241.50**	
	Total Difference in Savings (kW)				**12.95**

[a] Total savings difference due to rounding of average per-participant displayed values

During the 2014 treatment period of March 18, 2014 to December 31, 2014, a total of 3,265 energy efficiency measures were installed by customers assigned to the control group, 2,051 of them by September 15, 2014 (the 2014 heat wave). The total prorated rollover savings achieved by the 2014 control group through downstream measures during 2015 was 1,040,405 kWh and 228.55 kW. This is compared to a total of 3,425 energy efficiency measures installed by customers who received HER reports, 2,156 of them by September 15, 2014. The total prorated downstream savings from the treatment group for that period was 1,120,957 kWh and 241.50 kW. The difference between the two groups, the incremental savings resulting from HER that would be counted elsewhere, are 80,551.82 kWh and 12.95 kW.

2014 First vs Second Year Effects

The savings difference across treatment and control groups attributed to downstream programs during 2014 was 39,045 kWh. This is about half of the calculated savings difference (80,552 kWh) for the carry-over savings for those measures in 2015. The main difference is due to the fact that the second year effects are calculated for the full year, while the first year effects were prorated from March 18, 2014 (the start of the Opower-2 program) or the installation date (whichever came last). Therefore, the maximum number of prorated days during the first year was 288 compared to 365 during the second year; very few customers had installations for the maximum number of days in 2014.

2015 Total Downstream Savings Calculation

Tables 9 and 10 show the rollover kWh and kW savings respectively from the 2014 downstream measure installations. Table 9 shows the total kWh savings in 2015 for the Opower-2 customers that installed a downstream measure in either 2014 or 2015 as well as the incremental difference between the customers who received a HER and those who didn't. These tables simply combine the results of Tables 5-8 above.

Table 9. Total 2015 Incremental Downstream Savings from 2014 and 2015 Installations (kWh)

Measure	Control		Treatment		kWh Difference
	Customer Measure Count	kWh Savings [a]	Customer Measure Count	kWh Savings [a]	
Central AC	109	43,777.88	109	38,329.72	(5,448.15)
Evap Cooler	5	328.57	8	758.59	430.01
Lighting	156	15,814.24	225	20,391.40	4,577.16
In Home Survey	1	314.70	1	108.64	(206.06)
Mail Survey	4459	657,003.60	4409	649,075.90	(7,927.70)
Online Survey	4	392.06	3	154.20	(237.86)
Phone Survey	2	482.56	6	1,113.41	630.84
Pool Pump	173	87,963.14	210	98,662.72	10,699.58
Refrigerator	2136	912,090.14	2455	1,074,986.77	162,896.63
Whole House Retrofit	85	68,143.98	83	77,655.31	9,511.32
Heat Pump	1	261.97	0	-	(261.97)
Room AC	0	-	1	17.97	17.97
Clothes Washer	98	16,871.63	85	14,377.84	(2,493.79)
Attic Insulation	56	4,452.79	46	2,400.19	(2,052.60)
Whole House Fan	17	122.53	19	75.76	(46.77)
Total	**7,302**	**1,808,019.81**	**7,660**	**1,978,108.41**	
	Total Difference in Savings (kWh)				**170,088.60**

[a] Total savings differences due to rounding of average per-measure displayed values

Table 10 shows the analogous information for the total kW savings associated with the downstream programs for the 2015 program year. AEG calculated the kW difference by including the measures and kW savings for only those customers who had installed their measures by September 08, 2015, the first day of the 2015 heat wave period. That is why the kW customer counts are different from the kWh counts in Table 9. The individual kW values for each customer with peak day installations were not prorated since they reflect the demand savings on the peak day.

Table 10. Total 2015 Incremental Downstream Savings from 2014 and 2015 Installations (kW)

Measure	Control		Treatment		kWh Difference
	Customer Measure Count	kW Savings [a]	Customer Measure Count	kW Savings [a]	
Central AC	79	16.14	78	18.46	2.32
Evap Cooler	0	-	1	0.73	0.73
Lighting	142	2.87	219	3.73	0.87
In Home Survey	0	-	1	0.07	0.07
Mail Survey	3348	341.50	3319	338.54	(2.96)
Online Survey	0	-	0	-	-
Phone Survey	2	0.12	4	0.24	0.12
Pool Pump	133	17.92	174	14.89	(3.04)
Refrigerator	1464	168.83	1728	201.61	32.78
Whole House Retrofit	71	106.99	74	118.95	11.96
Heat Pump	1	0.15	0	-	(0.15)
Room AC	0	-	1	0.06	0.06
Clothes Washer	98	4.53	85	4.37	(0.15)
Attic Insulation	56	4.32	46	2.33	(1.99)
Whole House Fan	15	0.04	16	0.05	0.00
Total	**5,409**	**663.42**	**5,746**	**704.03**	
	Total Difference in Savings (kW)				**40.61**

[a] Total savings difference due to rounding of average per-participant displayed values

During the 2015 treatment period (including both 2014 and 2015 installations), a total of 7,302 energy efficiency measures were installed by customers assigned to the control group, 5,409 of them by September 08, 2015 (the 2015 heat wave). The total prorated rollover savings achieved by the control group through downstream measures during 2015 was 1,808,020 kWh and 663.42 kW. This is compared to a total of 7,660 energy efficiency measures installed by customers who received HER reports, 5,746 of them by September 08, 2015. The total prorated downstream savings from the treatment group during 2015 was 1,978,108 kWh and 704.03 kW. The difference between the two groups, the incremental savings resulting from HER that would be counted elsewhere, are 170,089 kWh and 40.61 kW.

2015 versus 2014 Downstream Savings Calculations

Table 11. 2015 Downstream Program Incremental Savings from 2014 and 2015 Installations

Incremental Savings	kWh	kW
2014 Installations (2nd year effect)	80,552	12.95
2015 Installations	89,537	27.66
Total Incremental Savings	170,089	40.61

Table 11 shows that the downstream savings calculations are quite a bit higher than those that were calculated in 2014. The 2014 downstream kWh difference was 39,045 compared to 170,088 kWh in 2015, while the kW difference in 2014 was 13.32 kW compared to 40.61 kW in 2015. There are several reasons for this.

The main difference is that for the 2015 program year, AEG also calculated the contributing second year effects from the 2014 downstream installation measures. In doing so, the second year kWh effect turned out to be almost double the first year impact. As mentioned above, this was due to fact that the 2014 first year effects were cut off by nearly three months since the HER program started in March 18, 2014 while the second year effects were for the full 2015 year. These additional months contributed to additional 40,507 kWh in savings for the second year compared to the first and resulted in 80,552 in second year savings. On the kW side, the savings decreased in the second year compared to the first (12.95 kW compared to 13.32 kW) due to the fact that there were 87 accounts that went inactive from 2014 to 2015.

The downstream kWh savings from the 2015 installations was also quite a bit higher than the 2014 first year savings but are actually very comparable to the second year savings from 2014 (89,537 kWh compared to 80,552 kWh). The kW savings however were about double those from the 2014 first and second year kW savings. This difference can be explained by the fact that the number of accounts going into the 2015 calculations was 6,948 compared to 4,207 accounts that went into the 2014 second year kW calculations. In addition, the number of treatment accounts over the control was also higher by over 100 accounts compared to 2014 (105 in 2014 compared to 232 in 2015) leading to a larger kW savings difference.

Chapter 6 – Attributing Savings to Upstream Programs

Upstream program savings are not tracked at the customer level, but are also a source of savings that can potentially be double counted by the HER program. SCE runs a program that provides incentives to manufacturers and retailers to change stocking practices of energy efficient CFLs and LEDs (Upstream Lighting Program or ULP). Since it is not possible to track which customers purchased bulbs at reduced prices, we used the proxy method developed in consultation with the CPUC ED to determine the savings that are potentially double-counted. While we are using the method as agreed to for this year's savings, we believe that the values used may warrant some refinement. Particularly, the savings values attributed to CFLs (45 kWh/year) appear to be much higher than those of PG&E (24 kWh/year) and SDG&E (18 kWh/year).

PG&E conducted in-home surveys[8] that assess the uptake of upstream measures (mainly, CFLs and flat screen TVs). The surveys included samples of treatment and control customers from PG&E's HER program. The CPUC ED has supported the use of these results for SCE, rather than duplicate that very costly and time-consuming study. This is also consistent with more recent lighting analysis memos produced by TRC.[9] The method assumes the same per-participant change in bulb installations (also referred to as "excess bulbs" below) resulting from HER participation for SCE as PG&E, and uses the results from that study as the basis for the estimate of the SCE upstream incremental savings.

In the PG&E survey report (and incorporated in the TRC memo), the analysis identified that, on average, treatment households installed an additional 0.95 energy efficient bulbs[10] per household more than the control group in the first year of the program. During the second year, the households continue installing energy efficient bulbs, but at a lower rate of 0.40 bulbs per household more than the control group. The TRC memo estimated that 72% of these bulbs were CFL and the balance, 28%, were LEDs.[11] As with the downstream savings described in the previous chapter, it is only the incremental difference between the treatment and control groups that would potentially be double counted. To reiterate, the assumption made in the use of the PG&E home study is that the increase in per customer lamp purchases resulting from receiving HERs is the same for the programs at the two different utilities. The additional bulbs per customer represent savings that could be potentially be counted by both the ULP and the Opower-2 program.

To calculate the Opower-2 customers who might have made installations, we made the additional assumption, consistent with the TRC proposed changes memo, that all the CFLs and LEDS were installed evenly (one-twelfth per month) throughout the first year and second year. Since the Opower-2 program savings analysis described in previous chapters only includes

[8] Freeman, Sullivan & Co, "Evaluation of Pacific Gas and Electric Company's Home Energy Report Initiative for the 2010–2012 Program," April 25, 2012. (aka PG&E home inventory study)

[9] TRC Solutions, "Lighting Savings Overlap in 2014 IOU Residential Behavioral Programs," June 27, 2016.

[10] Op cit, Freeman, Sullivan & Co, Table 7-3, p. 46. Surveys conducted in PG&E service territory; no data for SCE service territory available. Also used in TRC memo.

[11] TRC Solutions, "Lighting Savings Overlap in 2014 IOU Residential Behavioral Programs," June 27, 2016.

savings starting in April, we shifted the 0.95 excess bulbs to be installed evenly through April 2014 and March 2015 and the second year additional 0.40 excess bulbs to be installed evenly through April 2015 and December 2015 at 65,281 treatment households. We arrived at the total count of customers by removing both closed and address mismatched accounts from the total. This is the only place where we removed mismatched accounts in the entire study, in line with the TRC memo.[12]

The next step was determining what fraction of the savings for the additional bulbs are also counted as part of the ULP. According to the TRC work, a ratio of 0.4 of CFLs and 0.2 of LEDs received rebates statewide through the ULP, calculated as the total rebated CFLs divided by the total CFLs sold, and the same holding true for LEDs. Next, we determined the fraction of rebated CFLs and LEDs attributable to the ULP using the applicable net-to-gross ratio (NTGR). For the SCE territory, the most recent, approved upstream lighting net-to-gross ratio is 0.69.

2014 and 2015 kWh Savings

The final step was determining the expected total energy savings per year, based on the average hours of use per day and the average wattage saved per CFL and per LED. Based on information for SCE in the ULP report, the typical ULP CFL light bulb saves 45.2 kWh/year and the typical LED light bulb saves 19.9 kWh/year (compared to a CFL).

Multiplying all of these values together (shown below) gives us the respective CFL and LED incremental savings that need to be deducted from the total Opower-2 PY 2015 kWh savings estimate. Unless otherwise noted, the input values come from the TRC memos.[13]

[12] Op cit, TRC Solutions, June 30, 2015.

[13] Op cit, TRC Solutions, June 30 and October 22, 2015.

	2014	2015	
	0.95	0.54	Excess Bulbs (based on PG&E Home Inventory)
×	0.72	0.72	Fraction of Excess Bulbs sold that were CFLs
×	0.75	1.00	Fraction of Year program was running
×	0.97	0.97	Installation rate of rebated CFLs
×	65,281	65,281	Opower-2 HER customers[14]
×	1.00	0.50	Proration of full year savings to program year savings[15]
×	0.4	0.4	Proportion of CFLs that are rebated (statewide)
×	0.69	0.69	Proportion of CFLs attributable to upstream program (SCE specific)
×	45.2	45.2	Per CFL savings per year (SCE specific)
=	404,299[16]	152,499[17]	**CFL kWh of savings attributable to both programs**

	0.95		Excess Bulbs (based on PG&E Home Inventory)
×	0.28	0.28	Fraction of Excess Bulbs sold that were LEDs
×	0.75	1.00	Fraction of Year program was running
×	0.97	0.97	Installation rate of rebated CFLs
×	65,281	65,281	Opower-2 HER customers[18]
×	1.00	0.50	Proration of full year savings to program year savings[19]
×	0.2	0.2	Proportion of LEDs that are rebated (statewide)
×	0.69	0.69	Proportion of LEDs attributable to upstream program (SCE specific)
×	19.9	19.9	Per LED savings per year (SCE specific)
=	34,902[20]	13,165[21]	**LED kWh of savings attributable to both programs**

The total kWh savings attributable to the upstream lighting programs, based on this analysis approach, is the sum of these four estimates:

404,299 kWh + 34,902 kWh + 152,499 kWh + 13,165 kWh = 604,864 kWh

[14] Average number of customers from January-December of 2015 after removing Mismatched and Inactive accounts.
[15] Calculated as one half of the 12 months of the program, since the ramp up is assumed to be continuous throughout the first year.
[16] Different from the displayed numbers above due to rounding.
[17] Different from the displayed numbers above due to rounding.
[18] Average number of customers from January-December of 2015 after removing Mismatched and Inactive accounts.
[19] Calculated as half the proportion of the year from January to December.

2014 and 2015 kW Savings

In order to determine the incremental peak demand savings, we modified two of the values in the above kWh calculations.

First, we adjusted the value used for customers by using the number of Opower-2 participants in September 2015 (the heat wave month). The number of participants as of September 8th was 64,382 and 69% of all CFLs and LEDs installed during 2015 would have been installed by this time (based on the same assumptions used for the kWh estimate).

Second, we modified the CFL and LED savings per year value. This involved replacing the value for savings per year with the demand savings at peak. This value represents the estimated demand savings per light bulb during the 9 heat wave hours. It is the product of the kWh savings per bulb and the coincidence diversity factor for light bulbs. The coincidence diversity factor used was the weighted average of the coincidence diversity factors for the climate zones with participants, weighted by the number of participants in those climate zones. The diversity factor provided by the SCE engineers was 0.0449 watts at peak per kWh.

The calculation of CFL and LED incremental savings that needs to be deducted from the peak kW savings estimates are shown below. Again, unless otherwise noted, the input values come from the TRC memos.[22]

[20] Different from the displayed numbers above due to rounding.
[21] Different from the displayed numbers above due to rounding.
[22] Op cit, TRC Solutions, June 30 and October 22, 2015.

	2014	2015	
	0.95	0.54	Excess Bulbs (based on PG&E Home Inventory)
×	0.72	0.72	Fraction of Excess Bulbs sold that were CFLs
×	0.75	1.00	Fraction of Year program was running
×	0.97	0.97	Installation rate of bulbs
×	64,382	64,382	Opower-2 HER customers in September[23]
×	0.4	0.4	Proportion of CFLs that are rebated (statewide)
×	1.00	0.69	Proportion in place during system peak
×	0.69	0.69	Proportion of CFLs attributable to upstream program (SCE specific)
×	0.0020	0.0020	Per CFL kW savings at the peak (SCE specific) (45.2×0.0449÷1000)
=	17.94[24]	9.30[25]	**CFL kW savings at the peak attributable to both programs**

	2014	2015	
	0.95	0.54	Excess Bulbs (based on PG&E Home Inventory)
×	0.28	0.28	Fraction of Excess Bulbs sold that were CFLs
×	0.75	1.00	Fraction of Year program was running
×	0.97	0.97	Installation rate of bulbs
×	64,382	64,382	Customers in September[26]
×	0.2	0.2	Proportion of LEDs that are rebated (statewide)
×	1.00	0.69	Proportion in place during system peak
×	0.69	0.69	Proportion of CFLs attributable to upstream program (SCE specific)
×	0.0009	0.0009	Per CFL kW savings at the peak (SCE specific) (19.9×0.0449÷1000)
=	1.55[27]	0.80[28]	**LED kW savings at the peak attributable to both programs**

[23] Total number of active/non-mismatched customers as of 09/08/2015.
[24] Different from the displayed numbers above due to rounding.
[25] Different from the displayed numbers above due to rounding.
[26] Total number of active/non-mismatched customers as of 09/08/2015.

The total kW savings attributable to the upstream lighting programs, based on this analysis approach, is the sum of these two estimates:

$$17.94 \text{ kW} + 9.30 \text{ kW} + 1.55 \text{ kW} + 0.80 \text{ kW} = 29.59 \text{ kW}$$

A Note About the Upstream Methodology

The methodology used to calculate the incremental savings in SCE's Upstream Lighting Program (ULP) for Opower-2 PY 2015 conforms completely with the agreed-upon algorithms and input values in the TRC memo dated June 27, 2016 and cited above.

While we concur with these ED-approved algorithms for calculation of savings due to HER-induced lighting actions, we believe that many of the designated input values are of doubtful reliability and/or applicability to SCE's service area and program, resulting in overstatement of incremental savings. Specifically, these include:

- Number of bulbs purchased and installed—the data for the number of additional bulbs likely purchased due to the HER program are from a survey that is old and did not represent SCE customers well. The weakness of the statistical validity of these values, namely .95 bulbs per participant in the first HER program year and .4 bulbs in the second year, has been acknowledged. Of greatest concern is that these additional purchases include all additional bulbs purchased, not only those covered under the ULP.

- Similarly, the use of the survey-based estimate of a 97% installation rate for these additional bulb deserves renewed attention.

- Per-bulb savings—the designated savings estimate of 45 kWh/year assumes that every bulb purchased is as energy-efficient as those covered under the ULP. It is likely, however, that some portion of the purchases (amount unknown) are not this efficient and therefore, the savings are actually smaller than reflected in the value designated for SCE.

  We also note that the per-CFL values designated for SCE are considerably higher than for the other utilities (e.g., 45 kWh/year for SCE versus 24 and 18 kWh for PG&E and SDG&E, respectively) which is compounded by the estimates that a higher percentage of CFLs purchased are rebated under SCE's program than under the other utilities' (40% for SCE compared with 7% and 18% for PG&E and SDG&E, respectively) and that the share of CFLs to LEDs is purportedly higher in SCE's territory than in the other utilities.

The continued use of these input values especially burdens the SCE HER program because SCE's ULP is larger than PG&E's and SDG&E's. We recommend that, as new data become available, the approved methodology should be revisited and updated.

[27] Different from the displayed numbers above due to rounding.

[28] Different from the displayed numbers above due to rounding.

Chapter 7 – Final Results and Key Findings

Final 2015 HER Savings Results

The total estimated program Opower-2 PY 2015 program savings, showing the removal of upstream and downstream program savings are shown in Table 12.

Table 12. Total SCE Opower-2 PY 2015 HER Program Savings

	kWh	% of Energy [a]	% of Energy Savings [b]	kW	% of Demand [a]	% of Demand Savings [b]
Opower-2 PY 2015 Savings	5,340,297	1.0%	100.0%	799.6	0.4%	100.0%
Upstream Program Savings	604,864	0.1%	11.3%	29.6	0.0%	3.7%
Downstream Program Savings	170,089	0.0%	3.2%	40.6	0.0%	5.1%
Total Program Savings [c]	**4,565,344**	**0.9%**	**85.5%**	**729.4**	**0.4%**	**91.2%**

[a] The percentages in these columns are calculated against total household energy.

[b] The percentages in these columns are calculated against total savings.

[c] Total savings difference is due to rounding.

Key Findings

Key findings and conclusions from the 2015 analysis:

- **Statistically significant savings in all 2015 treatment months:** We estimate average direct program annual savings of 5,340 MWh, with statistically significant savings in every single month; and 800 kW peak load savings also statistically significant over the heat wave hours.
- **Larger kWh savings in summer months:** We estimate higher per-participant kWh savings in summer months when overall usage is highest. In percentage terms, summertime savings fluctuate around the annual average of 1.0%. Both the kWh and percentage savings are lowest in March 2015, which is among the lowest usage months, and also followed a longer than usual gap between HER reports, due to the change in program year.
- **Highest kW savings occur partially outside designated peak hours:** While the DEER-defined peak period is 2-5p, in 2015, the highest savings occur after the peak hours. This may suggest that the peak period is actually shifting.
- **Monthly energy savings exceed and peak savings equal previous program year:** 2015 was the second year of treatment with the same set of Opower-2 participants. The average monthly per-participant savings increased to 6.5 kWh from 5.7 in 2014, while the peak savings remains at .012 kW. Total annual kWh savings are notably higher than last year, in large part because the program was implemented for the full year rather than only nine months in 2014. As percent of total usage, the total kWh and kW savings are the same as last year.

- **Incremental savings account for 2-3 times as much of direct savings than previous year:** Since 2015 was the second year of treatment for the Opower-2 participants, the incremental savings from participation in other SCE programs includes effects from installations in both 2014 and 2015. This, in combination with an increase in other program installations in 2015 results in much higher savings removed from the direct HER program savings.
- **The upstream savings calculation methodology very likely overstates the true incremental savings:** While we concur with the ED-approved algorithm for calculation of savings due to HER-induced lighting actions, we believe that many of the designated input values are of doubtful reliability and/or applicability to SCE's service area and program, including number of bulbs purchased and installed, and per-bulb savings—resulting in overstatement of savings. We recommend that, as new data become available, the approved methodology should be revisited and updated.

Appendix

Appendix A – Fixed-Effects Final Regression Model Output

Full Model

Fixed-effects (within) regression		Number of obs	4,795,118
Group variable: account_id		Number of groups	147,004
R-sq:		Obs per group:	
within	0.4816	min	2
between	0.0285	avg	32.6
overall	0.2274	max	34
F(60,147003)=		8099.86	
corr(u_i, Xb)	0.0042	Prob > F	0.0000

Parameter Estimates					
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t-Value**	**Pr >|t|**
Intercept	1	539.2937	0.60946	884.87	<0.0001
norm_cdd	1	2.1691	0.00816	265.81	<0.0001
norm_hdd	1	0.0308	0.00332	9.29	<0.0001
m2	1	-27.8856	0.25432	-109.65	<0.0001
m3	1	-32.8132	0.35955	-91.26	<0.0001
m4	1	-42.1139	0.38909	-108.24	<0.0001
m5	1	0.4021	0.57327	0.70	0.483
m6	1	70.3536	0.71266	98.72	<0.0001
m7	1	170.9373	0.82742	206.59	<0.0001
m8	1	136.9170	0.84259	162.49	<0.0001
m9	1	149.6139	0.95724	156.30	<0.0001
m10	1	-1.7197	0.46171	-3.72	<0.0001
m11	1	-16.4170	0.30357	-54.08	<0.0001
m12	1	52.5164	0.37316	140.73	<0.0001
post2014	1	-40.1186	1.36462	-29.40	<0.0001
post2014xcdd	1	-0.4251	0.00879	-48.36	<0.0001
post2014xhdd	1	0.0737	0.00576	12.80	<0.0001
post2015	1	-51.7316	1.42647	-36.27	<0.0001
post2015xcdd	1	-1.2873	0.00737	-174.56	<0.0001
post2015xhdd	1	0.1440	0.00493	29.19	<0.0001
post2014xm3	1	15.1350	0.75526	20.04	<0.0001
post2014xm4	1	30.6147	0.91673	33.40	<0.0001
post2014xm5	1	36.2005	1.33981	27.02	<0.0001

post2014xm6	1	84.7039	1.48711	56.96	<0.0001
post2014xm7	1	74.0446	1.62026	45.70	<0.0001
post2014xm8	1	134.6190	1.72639	77.98	<0.0001
post2014xm9	1	67.5071	1.79758	37.55	<0.0001
post2014xm10	1	92.6711	1.33904	69.21	<0.0001
post2014xm11	1	26.9639	0.85833	31.41	<0.0001
post2015xm1	1	28.3165	0.77568	36.51	<0.0001
post2015xm2	1	16.4521	0.89469	18.39	<0.0001
post2015xm3	1	35.3220	1.01880	34.67	<0.0001
post2015xm4	1	38.1431	1.10933	34.38	<0.0001
post2015xm5	1	-8.6226	1.21677	-7.09	<0.0001
post2015xm6	1	39.2672	1.49957	26.19	<0.0001
post2015xm7	1	52.4787	1.68576	31.13	<0.0001
post2015xm8	1	164.4640	1.86318	88.27	<0.0001
post2015xm9	1	163.2414	1.94055	84.12	<0.0001
post2015xm10	1	175.4608	1.56176	112.35	<0.0001
post2015xm11	1	32.1765	0.87130	36.93	<0.0001
post2014xtrtxm4	1	-2.1239	0.53329	-3.98	<0.0001
post2014xtrtxm5	1	-4.5769	0.69831	-6.55	<0.0001
post2014xtrtxm6	1	-6.5536	0.90493	-7.24	<0.0001
post2014xtrtxm7	1	-7.8894	1.24485	-6.34	<0.0001
post2014xtrtxm8	1	-8.7329	1.34789	-6.48	<0.0001
post2014xtrtxm9	1	-6.1911	1.38710	-4.46	<0.0001
post2014xtrtxm10	1	-6.0797	0.82907	-7.33	<0.0001
post2014xtrtxm11	1	-5.0503	0.69095	-7.31	<0.0001
post2014xtrtxm12	1	-5.6963	0.87460	-6.51	<0.0001
post2015xtrtxm1	1	-4.9015	0.86817	-5.65	<0.0001
post2015xtrtxm2	1	-4.3021	0.75849	-5.67	<0.0001
post2015xtrtxm3	1	-4.1422	0.72666	-5.70	<0.0001
post2015xtrtxm4	1	-5.3437	0.72914	-7.33	<0.0001
post2015xtrtxm5	1	-5.9489	0.75007	-7.93	<0.0001
post2015xtrtxm6	1	-7.9098	1.06880	-7.40	<0.0001
post2015xtrtxm7	1	-9.4798	1.29639	-7.31	<0.0001
post2015xtrtxm8	1	-8.6073	1.56497	-5.50	<0.0001
post2015xtrtxm9	1	-7.7972	1.59296	-4.89	<0.0001
post2015xtrtxm10	1	-6.7722	1.18602	-5.71	<0.0001
post2015xtrtxm11	1	-6.7108	0.85121	-7.88	<0.0001
post2015xtrtxm12	1	-5.8205	1.10055	-5.29	<0.0001