SAFER, SMARTER, GREENER

Impact Evaluation Report

Home Energy Reports – Residential Program Year 2016

CALIFORNIA PUBLIC UTILITIES COMMISSION
CALMAC ID: CPU0190.01

May 1, 2019

Information	Details
Residential Sector Lead	Gomathi Sadhasivan
Project Manager	Lullit Getachew
Telephone Number	(510) 891-0446
Mailing Address	155 Grand Avenue, Suite 500, Oakland, CA 94612
Email Address	gomathi.sadhasivan@dnvgl.com, lullit.getachew@dnvgl.com
Report Location	http://calmac.org/ (CALMAC ID: CPU0190.01)

Table of contents

List of figures

List of tables

1 EXECUTIVE SUMMARY

1.1 Background

This report provides the results of the California Public Utilities Commission's (CPUC) evaluation of Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric's (SDG&E) Home Energy Reports (HER) programs for 2016. The evaluation conducted by DNV GL includes calculated energy and demand savings estimates that can be used to support SCE, SDG&E, and PG&E's savings claims for behavioral programs in 2016.

The residential sector accounts for 17% of the state's energy usage, with over 14 million single- and multi-family homes that house more than 39 million Californians. The primary purpose of energy efficiency behavioral programs is to reduce energy consumption by motivating no-cost and low-cost energy conservation actions and self-installation of energy saving measures. The HER programs aim to overcome market barriers and leverage social norms to nudge customer behavior. PG&E and SDG&E began sending home energy reports in 2011 and SCE began in 2012.

The reports sent to customers contain a mix of energy usage information, comparison of that usage with similar neighbors, and customized tips for saving energy. Over time, each program administrator has introduced new HER waves that draw from different populations and apply slightly different treatments. In this report, a "wave" is a sample of customers that are drawn for the HER program at a point in time. The waves are mutually exclusive, meaning a customer selected for one wave will not be in any other subsequent wave. Each wave has a treatment and control group to be studied, where both groups are exactly alike in all relevant ways, except the treatment group receives the home energy reports. The HER

evaluation for program year 2016 includes twelve HER program waves for PG&E, five for SDG&E, and three for SCE.

The HER programs use a randomized controlled trial (RCT) experimental design. The RCT experimental design is widely considered to be the most effective way to establish causality between a treatment and its effect. The approach uses substantial numbers of households in both treatment and control groups to produce an unbiased and precise estimate of savings. Opower, which implements the HER program for the program administrators, has used the RCT approach to support the credibility of program-related savings required by Commission decision.[1]

1.2 Research questions and objectives

The primary objective of this evaluation is to provide independent verification of energy and demand savings attributable to the HER program. Specific research questions include the following:

- Did the randomization process produce a balanced sample design for new waves? Was the sample design balance maintained after attrition for existing waves?
- What are the energy and demand savings for each HER wave?
- How much energy and demand savings can be jointly reported by both rebate programs and the HER program?
- What are the final energy and demand savings for each HER wave?

1.3 Study approach

To answer these research questions, DNV GL conducted an evaluation for the 2016 program year to estimate energy savings caused by the program, referred to as the program's "impact." DNV GL calculated the following energy and demand savings components:

- *Unadjusted savings.* These savings measure the overall impact of the HER program on average household energy consumption and demand usage before applying an adjustment for joint savings achieved in conjunction with other rebate programs. Unadjusted energy savings are estimated using a regression model that compares the difference between the treatment group's energy consumption to that of the control group, both before and after the home energy report receipt. Demand savings are estimated using another type of regression framework to estimate the reduction in peak load between the treatment group and control group during the hottest heatwave, also before and after the home energy report receipt.
- *Joint savings.* Joint savings represent an uplift in the treatment group's rebate program participation induced by HER. DNV GL estimated joint savings for downstream programs, where the rebate is offered downstream directly to the customer, and for upstream programs, where the rebate is offered upstream to the manufacturer:
  - *Downstream joint savings*. These savings occur when treatment group households increase their participation in tracked energy efficiency programs relative to control group households. As these savings are tracked for each customer, savings uplift can be measured directly.
  - *Upstream joint savings.* These savings occur when treatment group households increase their purchases of lamps rebated through the upstream lighting program. Because these savings cannot be

[1] Oracle Opower, formerly Opower, administers the HER programs.

tied directly to individual customers, survey results are used to measure uplift and other assumptions to estimate joint savings. Lamp uplift for HER program year 2016 was estimated based on over 19,000 responses to an online survey from treatment and control group customers across the three program administrators.

- *Adjusted savings.* These savings represent the final program savings after deducting both the downstream and upstream joint savings which are claimed by the rebated programs.

1.3.1 Total HER program savings

The HER program generated approximately 199,000 MWh in electric savings and 4.8 million therms in gas savings for program year 2016 across the three program administrators (Table 1-1). The HER program sample design continues to adhere to RCT standards for the majority of the cases enabling full program attribution for estimated savings.[2]

While the HER program has consistent savings of 1%-3% per household over time, total HER savings can erode due to attrition. However, the addition of new waves allows the program to continue contributing substantially to residential sector savings. Savings in program year 2016 either exceed or are in line with program year 2015 evaluated savings of approximately 150,000 MWh of electricity and 4.8 million therms of gas.

Table 1-1. Total HER Program savings in program year 2016

Type of Savings	PG&E	SDG&E	SCE
Electric (MWh)			
Unadjusted	148,536	26,821	35,464
Adjusted	138,381	26,316	33,830
Gas (therms)			
Unadjusted	3,929,466	768,382	N/A
Adjusted	4,049,741	757,093	
Peak Demand (MW)			
Unadjusted	35	7	14
Adjusted	33	7	13

[2] Apart from a couple of waves for one PA, balance tests indicate that the majority of cases adhere to the RCT standard.

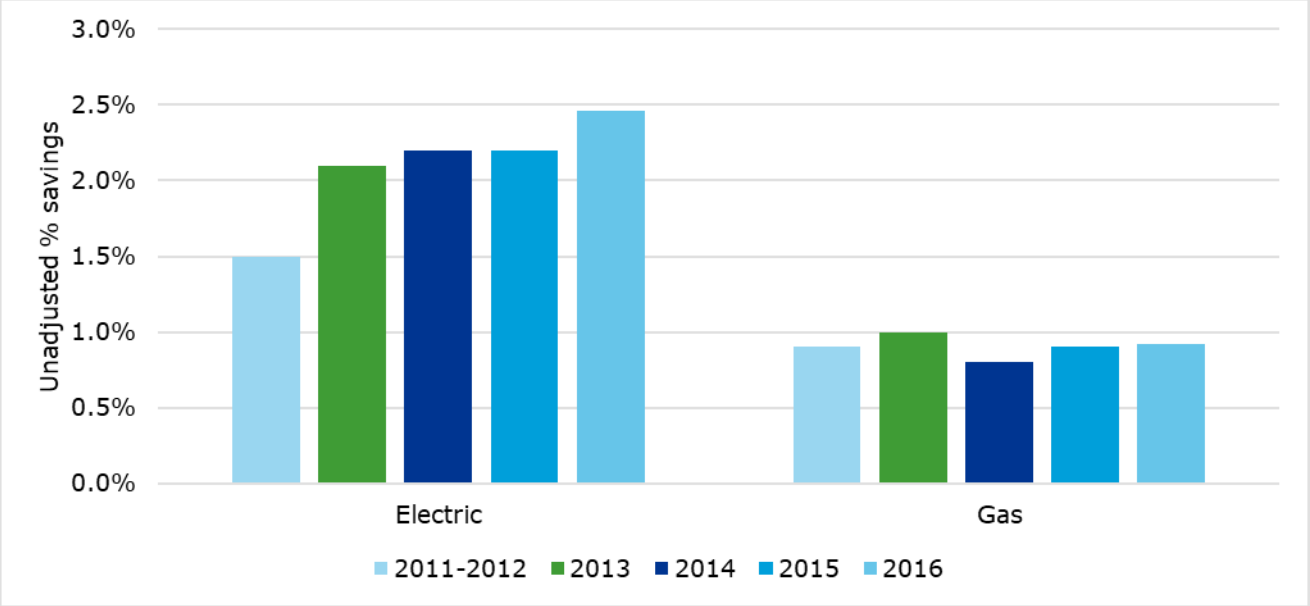
1.3.2 HER program savings trends

DNV GL conducted a trend analysis of HER program savings for each wave. The chart below illustrates this analysis and summarizes performance of PG&E's HER program introductory beta wave (Figure 1-1). The figure provides percent electric and gas savings from the launch of the program until 2016.

Electric savings are consistently higher than gas savings. Gas savings remain relatively lower and consistent over time. A plausible explanation for this observed difference between electric and gas savings is that gas use is tied to essential end-uses such as cooking and heating and hence customers have relatively less potential for gas reductions based on behavioral changes. Electric savings link to essential end-uses like lighting and cooling and also some non-essential ones such as entertainment and pool usage, which have elements that are more amenable to behavioral changes.

Electric savings ramp up after the first year and then stabilize as the program matures. As customers learn more about their consumption and actions, they may take to be more energy efficient, program savings start to increase. Savings stabilize as the number of energy-saving actions taken by customers begins to approach its maximum achievable potential.

Figure 1-1. PG&E HER program introductory beta wave % of household savings over time



1.3.3 HER program efficacy

The 2016 evaluation of the HER program shows that it achieved significant savings, a finding consistent with prior evaluations of the HER program. The chart below summarizes first-year percent electric and gas savings achieved for the introductory HER beta wave launched in 2011 and more recent waves 3, 4, 5, and 6 that were launched between 2013 and 2015 (Figure 1-2).

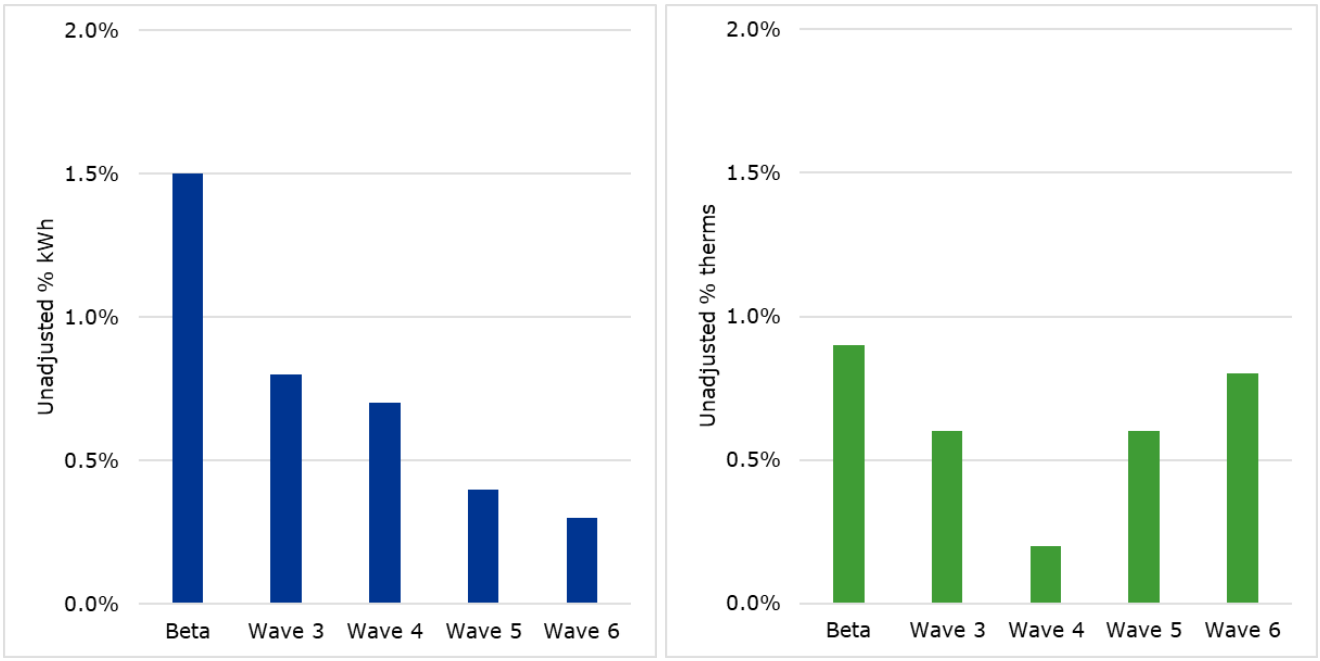
First-year electric savings achieved by more recent waves are notably lower than those that were achieved by the beta wave. Factors outside the program's influence contributing to this include an increased number of electronic devices in the home and electrification trends such as heat pumps, heat pump water heaters, electric vehicles etc. Additionally, the composition of recent HER waves includes customers drawn from lower

consumption quartiles of energy usage, not just the top quartile of highest-users where there is greater opportunity for savings.

Customers with lower levels of baseline energy consumption might have less potential for energy efficiency. There could also be changes in the energy consumption levels of the control group due to a variety of factors including increased awareness of the link between energy use and climate change.

It may also be the case that customers introduced to the HER program in more recent waves are receiving more information from other sources than new participants in prior years received and therefore may engage less with the HER report. Future evaluations should continue to monitor this and use insights to refine implementation for improved program performance.

Figure 1-2. First-year estimated savings for introductory and recent PG&E HER waves



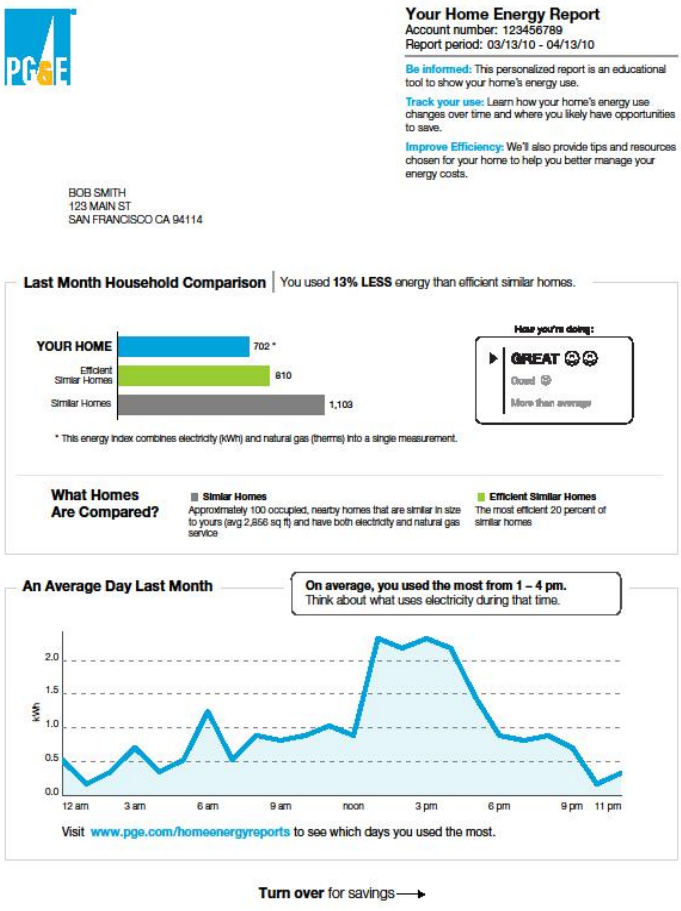
2 INTRODUCTION

2.1 Program description and participation

The residential sector accounts for 17% of the state's energy usage, with over 14 million single- and multi-family homes that house more than 39 million Californians. In 2012, the California Public Utilities Commission (CPUC) directed the California PAs to offer behavioral programs to at least 5% of households they serve. The CPUC further mandated that the offering employ a strategy of comparative energy usage following an experimental design approach.

Home Energy Reports (HERs) sent to customers contain a mix of energy usage information, comparison of that usage with similar neighbors, and customized tips for saving energy. An example of PG&E's HER is shown below (Figure 2-1). The primary purpose of the HER behavioral program is to reduce energy consumption by motivating no-cost and low-cost energy conservation actions and self-installation of energy saving measures. The evaluation also assesses whether the reports cause customers to participate in other energy efficiency programs as tracked by internal databases.

Figure 2-1. Example of a Home Energy Report



All of the PAs have comparative energy usage pilot programs that comply with the CPUC decision. Opower is the program implementer of the HER program for all PAs in California. PG&E and SDG&E began their HER programs in 2011 and SCE began in 2012. By the end of 2015, these reports constituted the largest single residential measure based on kilowatt-hours saved.[3] The HER program evaluation for 2016 includes PG&E, SCE, and SDG&E.

Over time, each program administrator has introduced new HER waves that draw from different populations and apply slightly different treatments. New waves are also introduced as replacements for program attrition. This attrition ranged from 5%-16% in the 2016 program year for all waves except SDG&E's Opower wave 3 Expansion Digital group. The attrition for both treatment and control households for this groups was 22% in 2016. Table 2-1 presents a summary of the HER program status as of 2016 for each of the PAs.

Table 2-1. HER 2016 program status

PA	Piloted in	Number of waves	Total 2016 residential households	Treatment	Control	Total active accounts in HER program in December 2016[4]	Program additions and changes
PG&E	August 2011	12	5,604,519	1,981,866	625,273	1,821,062	Most waves target highest usage quartiles.
SCE	December 2012	3	4,388,246	505,450	162,422	593,640	Opower 1 (introductory wave) discontinued.
SDG&E	July 2011	5	1,275,376	564,742	92,217	517,513	Digital reports added for waves launched from 2014 onwards.

2.2 Evaluation objectives

The primary objective of this evaluation is to provide independent verification of electricity and gas savings attributable to the HER program. Specific research questions and objectives include the following:

- Did the randomization process produce a balanced sample design for new waves? Was the sample design balance maintained after attrition for existing waves?
- What are the energy and demand savings for each HER wave?
- How much energy and demand savings can be jointly claimed by both the downstream and upstream rebate programs and the HER program?
- What are the final adjusted energy and demand savings for each HER wave by PA at the household and program levels? What percentage of consumption do these savings represent?

[3] CPUC Energy Efficiency Portfolio Report (May 2018). http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/About_Us/Organization/Divisions/Office_of_Governmental_Affairs/Legislation/2018/13-15%20Energy%20Efficiency%20Report_Final.pdf

[4] Active accounts are a subset of the sum of treatment and control customers enrolled in the HER program. This is due to attrition.

3 METHODOLOGY

3.1 Data sources

3.1.1 Program participants

Each of the PAs provided data on HER participants from all active waves. Appendix B includes a disposition of the customers involved in each PA's HER program. The data the PAs provided include participant account numbers (service agreement, customer, and premise numbers), the HER waves that each participant is in along with starting dates. Additional information such as if and when accounts become inactive, and email recipient and online accounts status are also included. These data served as the roster of program participants for the HER evaluation.

3.1.2 Monthly billing data

DNV GL used each PA's monthly billing data of HER customers to obtain energy use information for 12 pre- and for post-program months in 2016. The billing data included account numbers, premise numbers, billing cycle start and end dates, consumption reads, net metering flags, and the type of reading (i.e., actual meter reading/estimated reading).

3.1.3 Downstream program tracking data

DNV GL used CPUC program tracking data to collect information on PA's HER customers who participated in downstream rebate programs after the inception of the HER program. The CPUC tracking data included participant information, account numbers, program name, measures installed, installation dates, and claimed savings. This dataset facilitated calculating downstream joint savings for the program.

3.1.4 Online survey data

DNV GL conducted an online survey to assess efficient bulb uptake of all the PA's HER participants. The online survey collected information on the number of CFL and LED lamps purchased and installed by HER participants in the treatment and control groups. This survey facilitated calculating upstream joint savings for the program.

3.1.5 Hourly consumption data

DNV GL obtained sub-hourly or hourly electricity use data of HER customers for pre- and post-program summers for peak demand impact analysis of the HER program. The interval data included account numbers, service point id and 15-minute or 60-minute interval reading.

3.2 Energy savings

The baseline conditions for behavioral programs are the absence of the comparative reports. The RCT control group post-report data provides a robust proxy of treatment group baseline conditions. In the difference in difference structure, the difference between pre-report consumption offers an additional bias correction for minor random differences between the two groups. Household energy consumption is affected by a wide range of factors and it is difficult to establish the causality of the reports as the driver of pre- to post-installation changes. Random assignment of a control group that does not receive the reports allows for the most robust possible representation of baseline conditions.

DNV GL used a fixed effects regression model, a standard for evaluating behavioral programs like HER, for this evaluation, making it possible to compare consumption of the treatment group to the control group before and after program implementation. The change that occurs in the treatment group is adjusted to reflect any change that occurs in the control group, to isolate changes attributable to the program.

Below is the fixed-effects model specification used in this study:

$$E_{it} = \mu_i + \lambda_t + \beta_t P_{it} + \varepsilon_{it}$$

where:

E_{it} = Average daily energy consumption for account i during month t
P_{it} = Binary variable: one for households in the treatment group in the post period month t, zero otherwise
λ_t = Binary variable: one for a specific month/year, zero otherwise
μ_i = Account level fixed effect
ε_{it} = Regression residual

The average monthly savings are given by:

$$\bar{S}_t = \hat{\beta}_t$$

where:

$\bar{S}_t$ = Average treatment-related consumption reduction during month t
$\hat{\beta}_t$ = Estimated parameter measuring the treatment group difference in the post period month t

The model includes site-specific and month/year fixed effects. The site-specific effects control for mean differences between the treatment and control groups that do not change over time. The month/year fixed effects account for changes over time that affect both the treatment and control groups. The monthly post-program dummy variables pick up the average monthly effects of the treatment.

Households that moved out were dropped from the model as of the month they leave. The total savings are a sum of the monthly average savings combined with the count of households still eligible for the program in that month. Also, households that actively opted out of the program remain in the model as long as they remain in their house. In this respect, the treatment can be considered "intent to treat." This model is consistent with best practices as delineated in State and Local Energy Efficiency Action Network's Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations.[5]

3.3 Peak demand savings

Reductions in demand at peak times that result from HER program participation can be measured through a variety of approaches. The preferred approach in California is to examine differences in demand that occur during pre- and post-program peak periods. The peak period definition provided by the Database for Energy Efficiency Resources (DEER) was used for this purpose.[6] This definition considers the average temperature, average afternoon temperature (12 p.m.–6 p.m.), and maximum temperature over the course of three-day

[5] 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.

[6] http://www.cpuc.ca.gov/NR/rdonlyres/4F93F9C2-434E-4B06-8D80-B2CB7E0A4198/0/DEER2013UpdateDocumentation_792013.pdf

heatwave (HW) candidates. Each candidate HW is a combination of three consecutive non-holiday weekdays occurring between June 1 and September 30.

Using this definition, the optimal HW for each climate zone is ultimately selected by choosing the single candidate three-day-period with the highest peak score (Score_k) among all possible candidates.

The mathematical expression used to compute the peak score is given below:

$$HW = \max_{1 \le k \le K} (\text{Score}_k)$$

$$\text{Score}_k = \max_{1 \le d \le 3} (temp_{d,k}) + \frac{1}{d} \sum_{d=1}^{3} (daily\_mean_{d,k}) + \frac{1}{d} \sum_{d=1}^{3} (afternoon\_avg_{d,k})$$

Where

HW	=	Zone-specific set of three consecutive non-holiday weekdays that has the highest value of Score_k for heat wave candidate k across all possible candidates K
Score_k	=	The summation of maximum, average daily, and afternoon average temperature
$daily\_max_{d,k}$	=	The maximum hourly temperature value across all hours on day d, for heat wave candidate k.
$daily\_mean_{d,k}$	=	The average hourly temperature across all hours on day d, for heat wave candidate k.
$afternoon\_avg_{d,k}$	=	The average hourly temperature between 12 and 6 PM on day d, for heat wave candidate k.

DNV GL collected 15-minute and 60-minute interval data during the hours of 2 p.m.–5 p.m. of the most common heat wave in the pre- and post-periods for both treatment and control households. DNV GL then used a regression model based on average kW pre-post differences to estimate demand savings due to the HER program. The model estimates the difference-in-difference between treatment and control average DEER-defined demand and is specified as follows:

$$\Delta\overline{kW}_i = \alpha + \beta T_i + \varepsilon_i$$

Here:

$\Delta\overline{kW}_i$	=	Average pre-post demand difference for household i during the DEER-defined peak period
T_i	=	Treatment binary variable that takes the value of 1 if household i is in the treatment group and 0 if it is in the control
α, β	=	Model coefficients - β captures HER treatment effect on peak demand
ε_i	=	Model error term

3.4 Downstream rebate joint savings

One possible effect of the HER program is to increase rebate activity in other utility energy-efficiency programs. The RCT experimental design facilitates the measurement of this effect. DNV GL compared the average savings from rebate measures installed by the treatment group with the savings from measures installed by the control group. An increase in treatment group rebate program savings represents savings caused by the HER program jointly with the rebate programs. While these joint savings are an added benefit of the HER program, it is essential that these joint savings are only reported once. The most common and simple approach is to remove all joint savings from the HER program savings rather than remove program-specific joint savings from all of the associated rebate programs. This approach was used historically to adjust the savings from the behavioral programs.

The savings estimates from the fixed effects regressions include all differences between the treatment and control group in the post-report period. Joint savings are picked up by the regressions and are included in the overall savings estimate. These joint savings are also included in utility rebate program tracking databases and are claimed as part of those programs' savings unless further actions were taken to remove them. Savings from the HER program are adjusted using the joint savings estimates to avoid double counting of savings.

DNV GL used the following approach for rolling up individual rebate savings and calculating joint savings overall:

- Used accepted deemed savings values (those being used to claim the savings for the rebate program).
- Determined accumulated savings beginning from the installation date moving forward in time.
- Assigned daily savings on a load-shape-weighted basis (more savings are expected for periods when the measure is used more).
- Maintained the load-shape-weighted savings over the life of the measure.

This approach uses the deemed annual savings values and transforms them into realistic day-to-day savings values given the installation of that measure. DNV GL determined the daily share of annual savings using 2011 DEER hourly load shapes[7] for each PA.[8] These load shapes indicate when a measure is used during the year and, by proxy, when efficiency savings would occur.[9]

Savings for each installed measure start to accrue at the time of installation (or removal for refrigerator recycling). Average monthly household rebate program savings were calculated for the treatment and control groups including zeroes for the majority of households that did not take part in any rebate program. An increase in average per-household tracked program savings among the treatment group versus the control group indicates joint savings. DNV GL's recommended method for estimating joint savings analysis is consistent with the approach recommended in the SEE Action (State and Local Energy Efficiency Action Network) report.[10]

DNV GL used a similar approach to calculate potentially double counted savings in HER demand (kW) savings estimates, based on the use of deemed kW savings from measures installed during the treatment

[7] DEER load shapes are in an 8760-hourly format. DNV GL aggregated the hourly shares to daily shares in order to estimate daily savings.

[8] http://deeresources.com/DEER2011/download/DEER2011-UpdatedImpactProfiles-v2.zip

[9] This is more accurate and equitable than subtracting out the first-year savings values that are used in DEER, because most measures are not in place from the first day to the last day of the year.

[10] 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.

period but before the start of the peak period. The average deemed kW savings per household of the control group were subtracted from the average deemed kW savings per household of the treatment group to calculate joint savings between HER program and PG&E downstream rebate programs during the peak period.

3.5 Upstream joint savings

Upstream joint savings occur when a treatment group increases their purchases of CFL or LED lamps rebated through the upstream lighting program. Unlike tracked programs, it is not possible to directly compare all treatment and control group member activity. This makes it more challenging to determine if the HER program does increase savings in upstream programs.

DNV GL used survey results to measure uplift and then estimate upstream joint savings for each program year. The upstream joint savings equation used for calculating the annual electric savings and gas interactive effects is presented below:

$$Joint\ savings\ per\ household = Excess\ lamps\ due\ to\ HER\ x\ Rebated\ sales\ fraction\ x\ NTG\ x\ Installation\ rate\ x\ Installed\ proportion\ of\ 2016\ x\ Savings\ per\ lamp$$

Table 3-1 describes each upstream lighting joint savings input and lists the sources that are used for lamps installed between 2011 and 2016. Program administrator specific inputs are presented in Appendix D.

Table 3-1. Upstream lighting energy savings inputs

Variable	Description	Sources
Excess lamps (uplift) due to HER	Lamp uplift due to HER	2012 PG&E in-home survey, 2013 PSE HER phone survey (DNV GL), 2014 PSE HER phone survey (DNV GL), 2015 PA Residential Behavioral Programs: Online Survey Results (DNV GL, 2017), 2016-2017 PA Residential Behavioral Programs: Online Survey Results (DNV GL, 2019)
Rebated sales fraction	Proportion of lamps sold within the program administrator's territory that are rebated through the upstream lighting program	2014 and 2015 TRC HER lighting overlap studies
Installed share of 2016	Share of the year the lamps have been installed	Prior to 2016, 1; For 2016, .54 which assumes lamps are installed equally throughout the year, calculated as the average number of months a lamp is installed
Installation rate	Upstream lighting program lamp installation rate[11]	2013-14 ULP Evaluation (DNV GL, 2016)
Net-to-gross	Upstream lighting program average ex post net-to-gross factor	2010-12 ULP Evaluation (DNV GL, 2014), 2013-14 ULP Evaluation (DNV GL, 2016), 2015 ULP Evaluation (DNV GL, 2017)
Annual electric savings per lamp	Average ex post unit energy savings per lamp in the year of installation	2010-12 ULP Evaluation (DNV GL, 2014), 2014 TRC HER lighting overlap study, Program tracking data (DEER 2013-14), 2015 ULP Evaluation (DNV GL, 2017)
Gas interactive effects per lamp	Average ex-post interactive effects unit energy savings per lamp in the year of installation	2013-14 ULP Evaluation (DNV GL, 2016), 2015 ULP Evaluation (DNV GL, 2017)

As part of the program year 2017 evaluation, DNV GL conducted an online survey that informs the upstream lighting adjustment for the evaluations of program years 2016 and 2017.[12] The survey was used to update the efficient bulb uplift due to HER programs. The online survey included both treatment and control group households and collected information on their purchase and installation of CFLs and LEDs for the past year. The survey results were used to estimate the uplift in installed LEDs and CFLs.

Not all of the extra lamps installed due to the HER program may have been rebated through the upstream lighting program. The rebated sales fraction is used to adjust the uplift to the rebated proportion of excess lamps. It is assumed that excess lamps were installed evenly throughout the year; therefore, not all of the lamps installed in 2016 were installed in every month of the year. The average fraction of months that a bulb is installed out of a year is referred to as the installed proportion of 2016.[13]

[11] Not applicable after 2014 when the excess lamps due to HER switched to installed uplift rather than purchased uplift.

[12] Refer to "Impact Evaluation Report Home Energy Reports – Residential Program Year 2017," DNV GL for details of the survey. https://pda.energydataweb.com/api/view/2165/CPUC%20Group%20A%20Res%202017%20HER%20-%20Final_report.pdf

[13] A bulb installed in January is installed for 12 out of 12 months, a bulb installed in February is installed for 11 out of 12 months, and a bulb installed in December is installed for 1 out of 12 months. The average of these fractions is 0.54, which is the installed fraction used for the 2016 calculation.

Beginning in 2015, when DNV GL began the online survey, the measure of uplift shifted to installed lamps rather than purchased lamps; therefore, an installation rate was no longer necessary. DNV GL uses the installation rate from the 2013-2014 Upstream Lighting Program evaluation for lamps installed in earlier years (2011-2014).

The net-to-gross value and annual electric savings per lamp come primarily from past Upstream Lighting Program evaluations. The net-to-gross value is the average ex post net-to-gross CFL and LED factor weighted by the ex post quantity rebated for each IOU. The annual electric savings for 2016 and 2017 is the quantity weighted average ex post unit energy savings.

California recognizes the potential for interactive effects across fuels when assigning savings. Interactive effects are explicitly accounted for in the downstream rebate program tracking database. For the untracked Upstream Lighting Program, the quantity weighted average ex post unit energy savings (or dissavings) from past Upstream Lighting Program evaluations is used. The interactive effects produce negative gas joint savings and therefore increase the overall adjusted gas savings. This adjustment is important because the replacement of inefficient lighting measures with more efficient lamps can increase heating load consumption due to lower heat emissions from CFLs and LEDs.

The equation below shows the formula for the total upstream joint electric savings and interactive effects by wave:

$$Total\ upstream\ joint\ savings = Sum\Big(Treatment\ households_m\ x\ Sum\big(CFL\ joint\ savings\ per\ household_{m,y} + LED\ joint\ savings\ per\ household_{m,y}\big)\Big)$$

Total joint savings is calculated by first dividing the annual per household joint savings by 12 to calculate the monthly per household savings by lamp type (CFL and LED). Then, the CFL and LED monthly per household savings for all years are summed[14] and multiplied by the number of 2016 active treatment households in that month.[15] Finally, the monthly total savings are summed. Negative uplift, in which the control group installs more lamps than the treatment group, is included. This is done in order to adjust for changes in lamp installation over time. If the total upstream joint savings is negative, it is treated as a zero as no savings would be claimed jointly with the Upstream Lighting Program.

The upstream joint demand reduction equation is presented below, followed by Table 3-2 which describes the parameters used that are not addressed in Table 3-1.

$$Demand\ reduction\ per\ household = Excess\ lamps\ due\ to\ HER\ x\ Rebated\ sales\ fraction\ x\ NTG\ x\ Installation\ rate\ x\ Proportion\ of\ lamps\ installed\ at\ peak\ x\ Delta\ watts/1000\ x\ Peak\ coincidence\ factor$$

[14] None of the lamps installed due to HER uplift have reached their estimated useful life. For CFLs installed between 2011 and 2015, the estimated useful life is 9.7 years based on DEER 2014. For CFLs installed after 2015, the estimated useful life is 3.5 years based on DEER 2016. All LEDs have an estimated useful life of 16 years from DEER 2014 and DEER 2016. Once a lamp reaches its estimated useful life, it will no longer be included in the upstream lighting calculation.

[15] For example, all of the January joint savings per household across years are summed and then multiplied by the number of active treatment households in January 2016.

Table 3-2. Upstream lighting peak demand reduction inputs

Variable	Description	Sources
Percentage of lamps installed at peak	The percentage of lamps that are expected to be installed when the heatwave occurs	Calculated as the percent of days up through when heatwave occurs
Delta watts	The measure of instantaneous demand reductions in watts that results from replacing an inefficient incandescent bulb with a CFL, LED, or another bulb type	2015 ULP Evaluation (DNV GL, 2017)
Peak coincidence factor	the average percent of time that a lamp is switched on during the peak period	2015 ULP Evaluation (DNV GL, 2017)

Assuming equal installation throughout the year, not all lamps installed in 2016 would have been installed at the time of the peak period. This is adjusted by applying a factor calculated as the day of the year when the peak event began divided by 365 days. The impact of the watts reduction at peak is estimated by using the delta watts and the peak coincidence factor from the most recent Upstream Lighting Program evaluation.

The following is the equation used to calculate total peak demand reduction due to joint savings with the upstream program:

$$Total\ upstream\ joint\ peak\ demand\ reduction = Sum(Treatment\ households\ at\ peak\ x\ (CFL\ peak\ demand\ reduction\ per\ household + LED\ peak\ demand\ reduction\ per\ household)$$

4 SDG&E IMPACT RESULTS

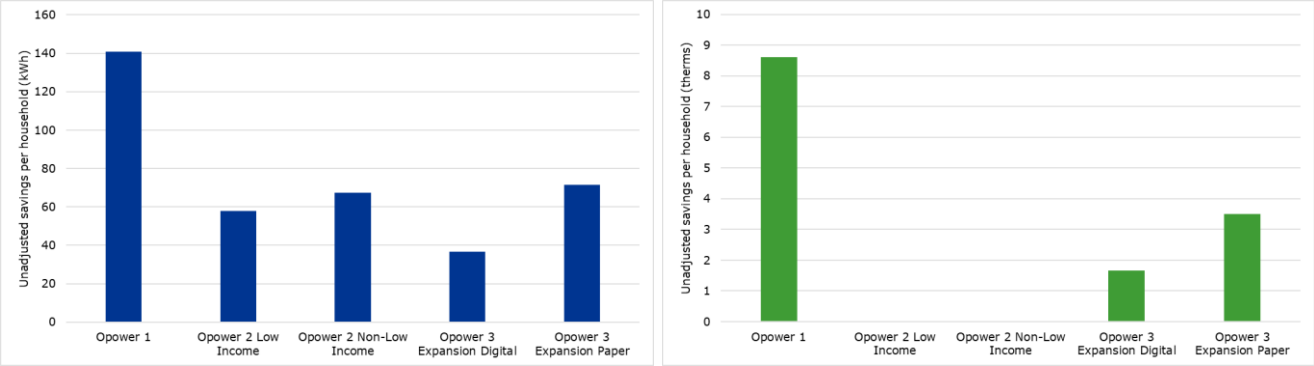
4.1 Unadjusted kWh and therm savings estimates

There are five experimental waves in the SDG&E HER program in 2016. Opower 1 and the two groups in Opower 2 (low and non-low-income) have been around since 2011 and 2014, respectively. Opower 3 has been in the field since the start of 2016 and has not been evaluated before.

Opower 3 consists of two expansion groups that were initially set up as digital and paper groups. Despite the name, the roster from Opower indicates that 60% of the paper group received HER reports both digitally and via paper. Almost all members of Opower 3 digital treatment households received both digital and paper HER reports.

Figure 4-1 presents the unadjusted electric and gas savings per household. The extent of energy use reduction per household does not seem to depend on how long the HER experimental wave has been in the field. Opower 1, the oldest wave, shows among the highest reduction while Opower 3 paper group, one of the more recent waves, also shows relatively high energy use reductions. Opower 2 groups do not show statistically detectable gas reductions in 2016.

Figure 4-1. SDG&E unadjusted electric and gas savings per household per year



In general, higher baseline use is associated with greater the energy use reduction from HER treatment. Opower 1 and Opower 3 paper group have the two highest baseline energy use and reductions due to HER. Table 4-1 also shows the highest per household electric (kWh) and gas (therm) savings are for Opower 3 paper and Opower 1 treatment households. These are composed of households with the highest baseline electric and gas consumption.

Table 4-1. SDG&E unadjusted electric and gas savings

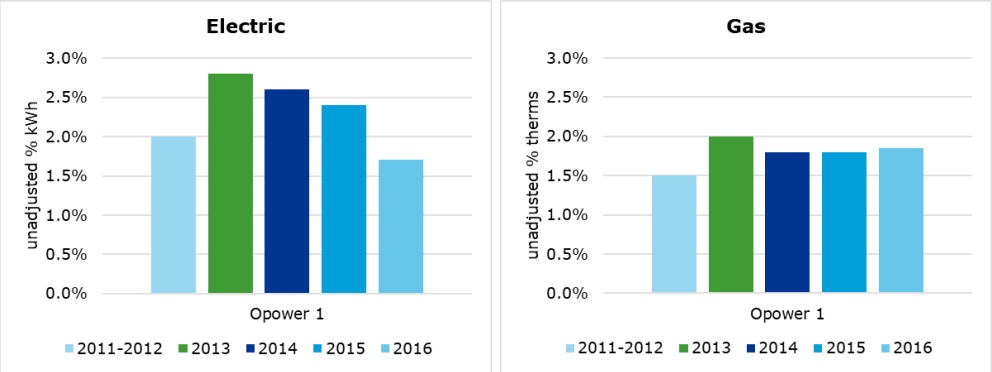
Wave	Baseline Consumption	Average Treatment Participants	Unadjusted Savings				
			Per Household per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Electric (kWh)							
Opower 1	8,250	13,469	141	1,895,673	737,368	3,053,979	1.7%
Opower 2 Low Income	5,149	18,855	58	1,088,936	208,792	1,969,079	1.1%
Opower 2 Non-Low Income	4,736	40,934	67	2,761,026	1,419,365	4,102,686	1.4%
Opower 3 Expansion Digital	4,701	224,598	37	8,227,260	5,366,577	11,087,944	0.8%
Opower 3 Expansion Paper	9,673	179,869	71	12,847,674	7,114,768	18,580,580	0.7%
Gas (therms)							
Opower 1	466	13,501	9	116,301	51,810	180,791	1.8%
Opower 2 Low Income	255	15,821	<1	5,963	-25,453	37,379	0.1%
Opower 2 Non-Low Income	238	28,817	<1	-15,457	-61,193	30,280	-0.2%
Opower 3 Expansion Digital	243	149,786	2	248,140	119,981	376,299	0.7%
Opower 3 Expansion Paper	369	118,331	3	413,434	173,857	653,011	0.9%

Note: The average number of treatment participants are reported to indicate wave size. Total unadjusted savings are based on monthly treatment counts.

Moreover, per household reductions as a percent of baseline energy use are higher for electricity than for gas. This could be because electricity use has more discretionary elements (such as entertainment) and elements that are more amenable to behavioral changes (e.g., turning off lights and unplugging electrical loads when not in use). Gas use tends to be for necessities, such as cooking and heating, which are less amenable to behavioral changes.

Figure 4-2 also illustrates that savings as a percent of baseline energy use are greater for electricity use than for gas. It shows that after initial ramp-up periods, electric savings as a percent of baseline energy use decline. Gas savings, relative to baseline gas use, on the other hand, are stable and do not exhibit any particular pattern. This is fitting with the conjecture that electric savings are tied more to behavioral changes that can give an initial boost in savings, but are may not contribute to sustained reductions.

Figure 4-2. SDG&E unadjusted percent electric and gas savings over time



4.2 Joint savings: downstream programs

Downstream joint savings are identified by comparing savings of the treatment and control groups from downstream program installations. These savings from measure installations build up over time in the post-treatment period. If the HER program motivates increased participation in other SDG&E programs, the treatment group downstream savings will accrue faster than the control group. The difference in savings between the treatment and control groups represents the savings jointly attributable to both the HER program and other downstream programs.

Figure 4-3 and Figure 4-4 provide the estimates of average joint electric and gas savings per customer in kWh and therms, respectively. These figures along with their confidence bounds indicate limited increased uptake of downstream rebate programs among treatment groups in 2016.

Figure 4-3. SDG&E electric downstream joint savings per household per year

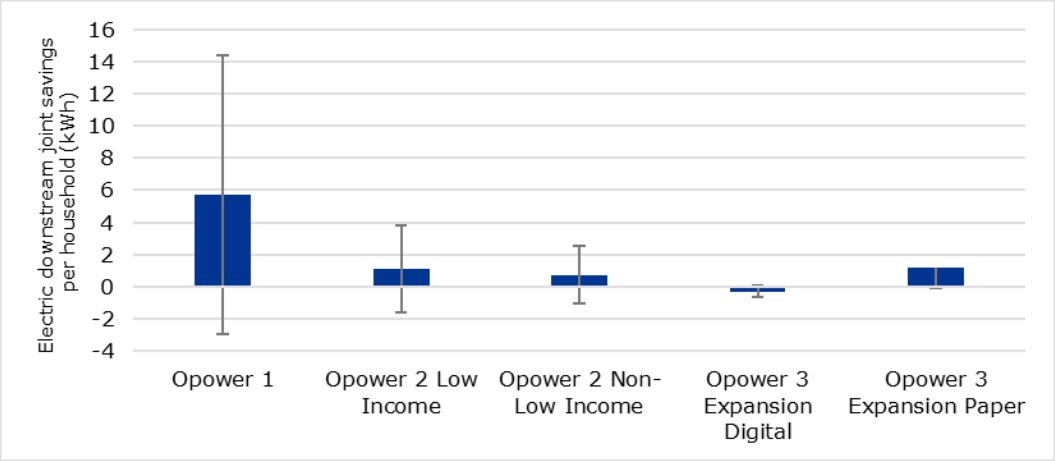
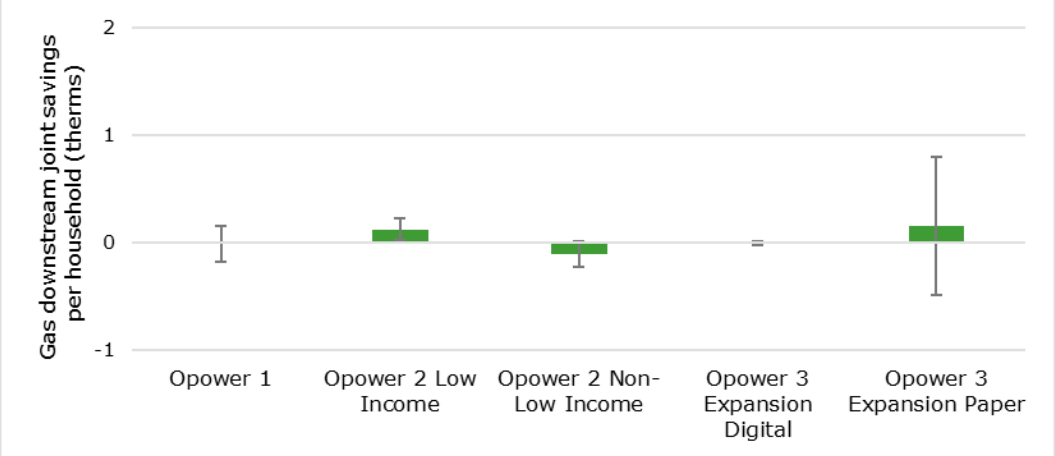


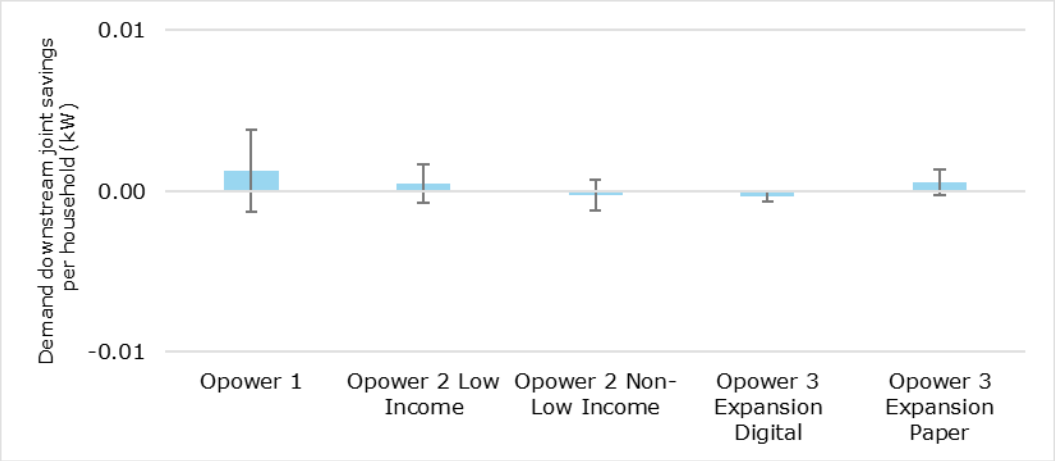
Figure 4-4. SDG&E gas downstream joint savings per household per year



The issue of potential double counting also applies to demand impacts to the extent that HER programs successfully motivate increased uptake in other energy efficiency programs and those programs claim demand savings. DNV GL calculated joint savings that are attributed to downstream rebated measures by using deemed demand values contained in downstream rebate tracking data and only by using those

measures installed prior to September 26, 2016, the first day of the most common heat wave in 2016. Figure 4-5 shows the downstream kW savings per household.

Figure 4-5. SDG&E downstream joint peak demand reduction per household per year



Together these figures indicate the presence of limited joint savings from increased uptake of downstream rebate programs due to HER among the treatment group in 2016.

Table 4-2 provides total downstream joint savings by wave. SDG&E HER treatment groups had 338 MWh, 30,000 therms, and 0.1 MW of peak demand joint savings in 2016 motivated by the HER program.

Table 4-2. Total SDG&E downstream joint savings by wave

Wave	Electric (kWh)	Gas (therms)	Peak Demand (kW)
Opower 1	77,250	0	16.5
Opower 2 Low Income	20,284	2,272	7.3
Opower 2 Non-Low Income	30,140	0	0
Opower 3 Expansion Digital	0	0	0
Opower 3 Expansion Paper	210,483	27,390	92.7

4.3 Joint savings: upstream programs

Upstream joint savings are like downstream joint savings, except that upstream savings are not tracked at the customer level. SDG&E upstream savings still represent a source of savings that the HER program could potentially double count. Unlike tracked programs, it is not possible to directly compare all treatment and control group member activity. This makes it more challenging to determine if the HER program does increase savings in upstream programs.

The alternative to the downstream census-level approach is to do a comparison of treatment and control group uptake of the upstream program measures on a sample basis. This approach also takes advantage of the RCT experimental design that provides the structure to produce an un-biased estimate of upstream savings. In 2017, DNV GL conducted an online survey to assess uptake of upstream measures (specifically, CFLs and LEDs) due to HER. The surveys included treatment and control customers from the SDG&E HER program.

Table 8-8 in Appendix D presents the uplift of CFL and LEDs for each of SDG&E's experimental waves. The results show there were uplifts of 0.74 LEDs for Opower 1 and of 0.2 for both CFL and LEDs for Opower 5. The rest of the waves had negative bulb uplift indicating that the control group purchased and installed more efficient bulbs than the treatment group.

Table 4-3 shows the kWh joint savings estimates per household. HER program savings are adjusted downwards by the upstream joint savings amounts for these waves. The total upstream joint savings per household for Opower 1 are 10.4 kWh per household for CFLs and 1.9 kWh for LEDs. The upstream joint savings per household for the rest of SDG&E's waves are negative, which indicates that the control group purchased and installed more bulbs than the treatment group. No adjustments due to upstream joint savings are applied to waves with negative uplift.

The replacement of inefficient lighting measures with efficient lamps is associated with an increase in heating load due to lower heat emissions from CFLs and LEDs. These interactive effects translate to a gas penalty that would have been double counted by HER. Table 4-4 presents total interactive therm effects by wave. Negative numbers are subtracted from unadjusted gas savings to remove the gas penalty associated with the removal of electric joint savings from upstream programs.

Table 4-3. SDG&E upstream joint savings per household per year

Wave	Upstream Joint Savings per Household per Year				
	Electric (kWh)			Interactive Effects (therms)	Peak Demand (kW)
	CFL	LED	Total		
Opower 1	10.4	1.9	12.3	-0.2	<0.1
Opower 2	-0.1	-1.7	0.0	0.0	0
Opower 3	-0.5	-2.5	0.0	0.0	0

Overall, total program joint savings due to participation in the upstream program are 166 MWh and 11 kW for Opower 1. There are no upstream joint savings for the rest of SDG&E's waves. (Table 4-4).

Table 4-4. SDG&E total upstream joint savings

Wave	Total Upstream Joint Savings		
	Electric (kWh)	Interactive Effects (therms)	Peak Demand (kW)
Opower 1	166,156	-2,917	11
Opower 2 Low Income	0	0	0
Opower 2 Non-Low Income	0	0	0
Opower 3 Expansion Digital	0	0	0
Opower 3 Expansion Paper	0	0	0

4.4 Demand savings estimates

Peak demand savings estimates are based on peak period (heat wave) definitions. The period that defines peak demand conditions that is used to estimate peak demand reductions is presented in section 4.4.1. Peak demand reductions for SDG&E's HER waves are presented in section 4.4.2.

4.4.1 Heat waves

DNV GL identified the 2016 heat waves using weather data from NOAA that contained hourly temperatures from weather stations across the SDG&E service territory from 2013 – 2016. The 3-day heat wave for 2016 fell on September 26 – September 28 (Table 4-5).

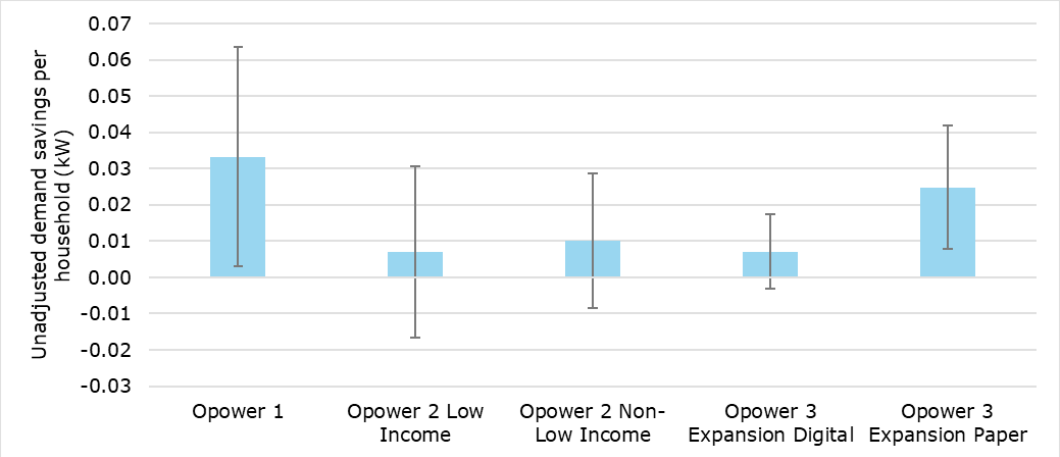
Table 4-5. SDG&E DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2016 Post-Period
Opower 1	9/27/2010	-	9/29/2010	9/26/2016 - 9/28/2016
Opower 2 Low Income	9/15/2014	-	9/17/2014	
Opower 2 Non-Low Income	9/15/2014	-	9/17/2014	
Opower 3 Expansion Digital	9/8/2015	-	9/10/2015	
Opower 3 Expansion Paper	9/8/2015	-	9/10/2015	

4.4.2 Peak demand reductions

The average three-hour reduction during the peak period for all SDG&E HER waves were a small fraction of a kW, with estimated values that are less than 0.1 kW. These values are statistically significant for two out of the five waves (Opower 1 and Opower 3 Expansion Paper) under consideration (Figure 4-6).

Figure 4-6. SDG&E unadjusted peak demand reduction per household per year



The estimated values, although small, are used to arrive at total peak demand reduction that result due to HER. Opower 3 Expansion Paper produced the highest unadjusted total peak savings at 4.4 MW (Table 4-6).

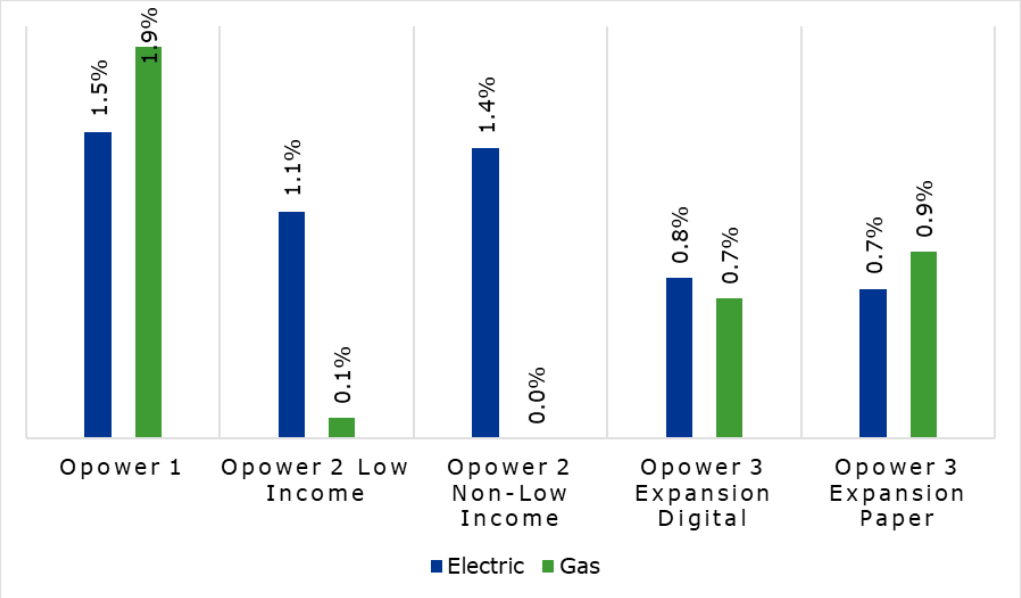
Table 4-6. SDG&E total unadjusted peak demand reduction

Wave	Active Accounts during Peak Period (September 26 – 28, 2016)	Total Peak Reduction (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Opower 1	13,274	442	42	842
Opower 2 Low Income	18,220	128	-301	557
Opower 2 Non-Low Income	39,607	404	-331	1,139
Opower 3 Expansion Digital	217,761	1,543	-687	3,772
Opower 3 Expansion Paper	177,112	4,392	1,379	7,405

4.5 Total program savings

Results in prior sections on unadjusted kWh and therm savings per household, and downstream and upstream joint savings per household are combined to determine adjusted savings per household. Figure 4-7 presents adjusted electric and gas savings per household as a percent of baseline consumption for each of SDG&E's waves. Adjusted savings as a percent of total consumption average about 1% for electric and 0.7% for gas. Table 8-11 and Table 8-12 in Appendix E present these results along with the tracked downstream and untracked upstream adjustments at the wave level.

Figure 4-7. SDG&E percent electric and gas savings by wave



SDG&E's HER program generated total savings of 26,316 MWh, 757,093 therms, and 6.8 MW in program year 2016 in Table 4-7 and Figure 8-1.

Table 4-7. SDG&E total savings for the 2016 HER programs

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	26,820,569
Joint Downstream	338,156
Joint Upstream	166,156
Adjusted	26,316,257
Gas (therms)	
Unadjusted	768,382
Joint Downstream	29,662
Joint Upstream	-2,917
Adjusted	757,093
Peak Demand (kW)	
Unadjusted	6,909
Joint Downstream	117
Joint Upstream	11
Adjusted	6,781

5 PG&E IMPACT RESULTS

5.1 Unadjusted kWh and therms savings estimates

PG&E has the greatest number of HER waves in the field. Energy savings from these waves in 2016 are presented in this section. As Figure 5-1 indicates, the Beta wave produced the highest per-household savings at 233 kWh in 2016. Unlike all other waves, participants for this wave are drawn from the highest usage quartile in the San Francisco Bay Area. Other waves include participants either from the highest 3 usage quartiles or from all usage quartiles.

Although the difference in per household savings is not always tied to baseline usage levels, there is a general pattern of higher savings for waves with higher baseline usage levels; the two waves with the highest per household savings are waves with baseline usage that are among the highest. Gas reductions indicate similar patterns. Per household savings are highest for Beta wave and the top savings per household are for waves with the highest baseline use.

Figure 5-1. PG&E unadjusted electric and gas savings per household per year

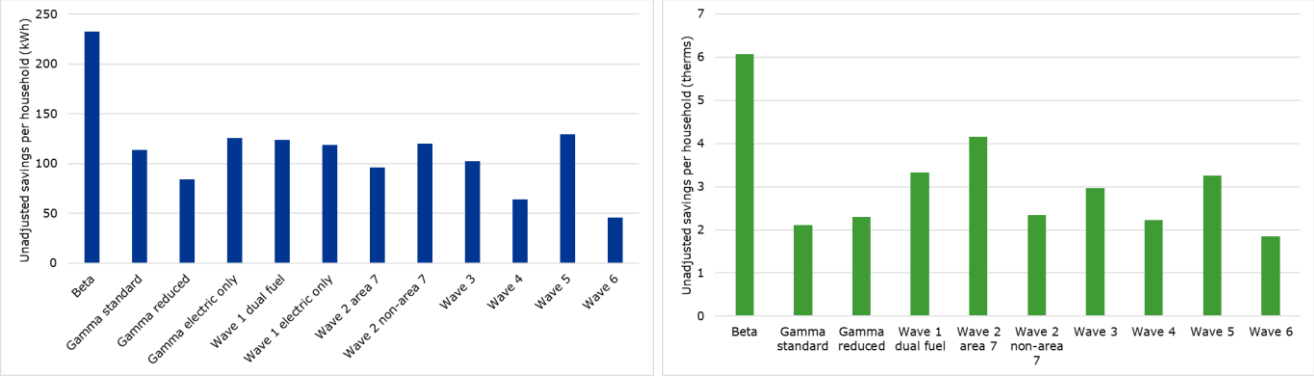


Table 5-1 presents percent savings in electric and gas use. Percent reductions in electric use ranged from about 1% to 2%. The Beta wave produced the highest electric percent savings at 2.5%. Percent reduction in gas use relative to baseline ranged from 0.5% to 1% in program year 2016. Gas reductions are similarly lower than electric savings as percent of baseline use.

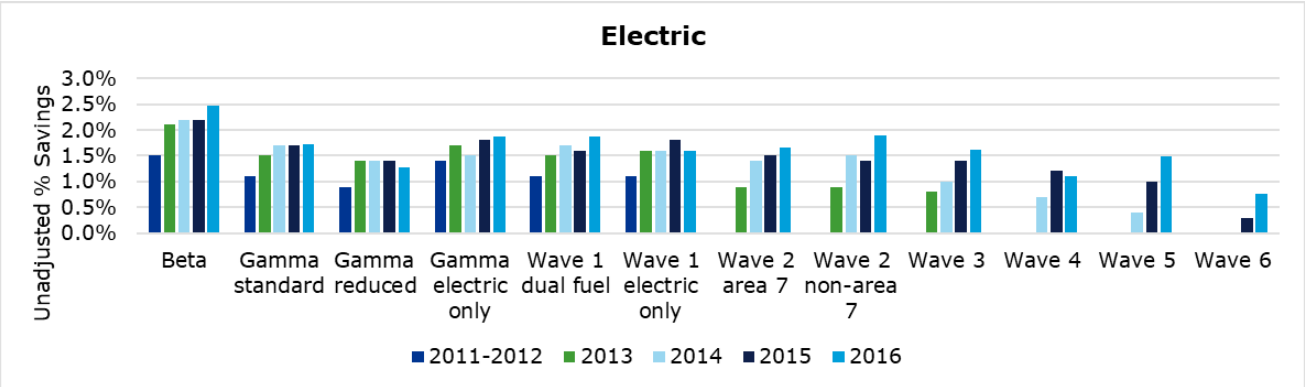
Table 5-1. PG&E unadjusted electric and gas savings

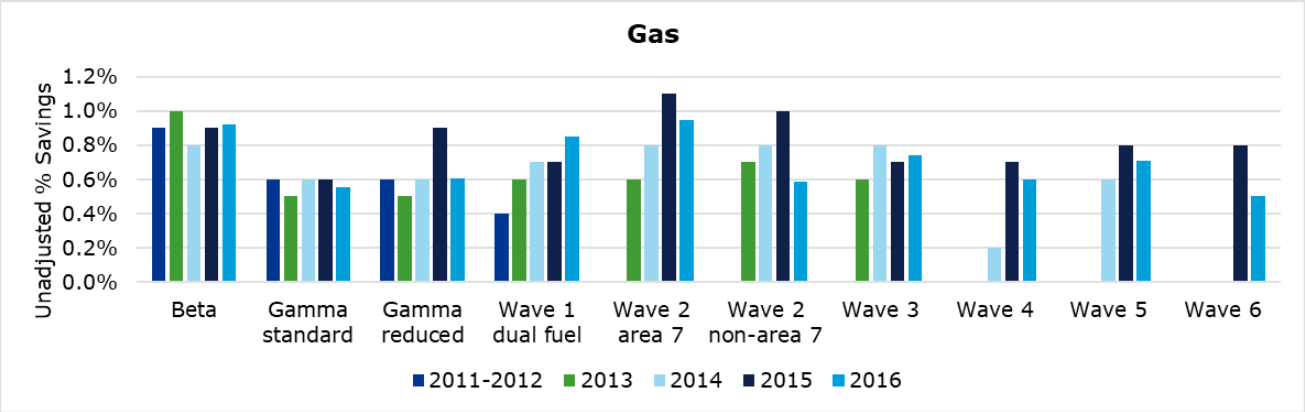
Wave	Baseline Consumption	Average Treatment Participants	Unadjusted Savings				
			Per Household per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Electric (kWh)							
Beta	9,448	42,474	233	9,880,662	8,006,781	11,754,543	2.5%
Gamma standard	6,613	48,850	114	5,551,761	3,891,105	7,212,417	1.7%
Gamma reduced	6,613	48,843	84	4,111,601	2,496,536	5,726,666	1.3%
Gamma electric only	6,678	24,388	125	3,059,022	1,971,634	4,146,410	1.9%
Wave 1 dual fuel	6,617	253,385	124	31,323,776	26,116,975	36,530,577	1.9%
Wave 1 electric only	7,459	23,651	119	2,812,019	819,795	4,804,244	1.6%
Wave 2 area 7	5,748	60,218	96	5,771,631	4,085,515	7,457,747	1.7%
Wave 2 non-area 7	6,347	231,223	120	27,662,036	22,293,454	33,030,619	1.9%
Wave 3	6,345	159,139	103	16,333,184	12,666,317	20,000,050	1.6%
Wave 4	5,803	139,519	64	8,952,106	5,884,467	12,019,746	1.1%
Wave 5	8,696	163,481	130	21,198,074	16,396,799	25,999,349	1.5%
Wave 6	5,949	261,008	46	11,880,382	7,825,745	15,935,019	0.8%
Gas (therms)							
Beta	657	42,585	6	258,267	149,980	366,554	0.9%
Gamma standard	382	48,901	2	103,203	26,114	180,293	0.6%
Gamma reduced	382	49,130	2	113,195	36,882	189,509	0.6%
Wave 1 dual fuel	392	253,115	3	843,654	576,186	1,111,121	0.9%
Wave 2 area 7	439	60,284	4	250,135	159,965	340,305	0.9%
Wave 2 non-area 7	401	232,092	2.3	544,420	253,188	835,652	0.6%
Wave 3	401	160,476	3	475,254	301,106	649,402	0.7%
Wave 4	369	139,375	2	309,563	168,795	450,331	0.6%
Wave 5	458	164,443	3	535,410	325,981	744,838	0.7%
Wave 6	369	267,930	2	496,365	285,042	707,689	0.5%

Note: The average number of treatment participants are reported to indicate wave size. Total unadjusted savings are based on monthly treatment counts.

Figure 5-2 shows the historical electric and gas savings trends for all PG&E HER waves. In general, the electric savings show a similar pattern of ramping up over time whereas gas savings do not exhibit a consistent ramp-up period. The beta wave targeted the highest usage quartile, the gamma waves targeted all usage quartiles, and waves 1 through 6 targeted the highest 3 usage quartiles. When comparing savings for wave 1 to 6, which target the same usage quartiles, it is apparent that later waves (waves 3 to 6) have lower savings (averaging 1%) than earlier waves (waves 1 and 2, with 1.5% average savings).

Figure 5-2. PG&E unadjusted percent electric and gas savings over time





5.2 Joint savings: downstream programs

Downstream joint savings are identified by comparing savings of the treatment and control groups from downstream program installations. These savings from measure installations build up over time in the post-treatment period. If the HER program motivates increased participation in other PG&E programs, the treatment group downstream savings will accrue faster than the control group. The difference in savings between the treatment and control groups represents the savings jointly attributable to both the HER program and other downstream programs.

Figure 5-3 through Figure 5-5 provide the estimates of average joint electric and gas savings per customer in kWh, and therms, respectively. The majority of the waves produced positive and relatively small joint savings per household that do not exceed 7 kWh. All waves produced statistically insignificant therm savings that do not exceed 1 therm per household; in fact, no wave has joint downstream HER savings that exceed a fraction of a therm.

Figure 5-3. PG&E electric downstream joint savings per household per year

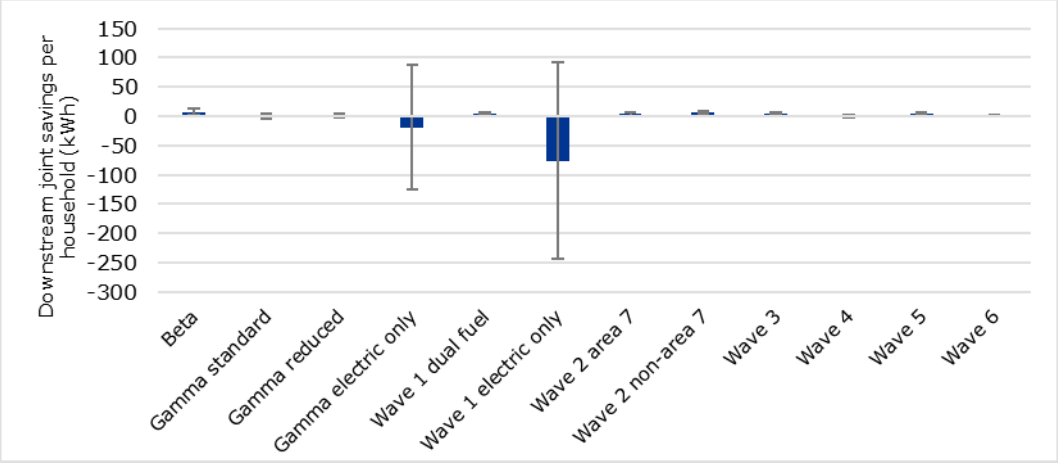
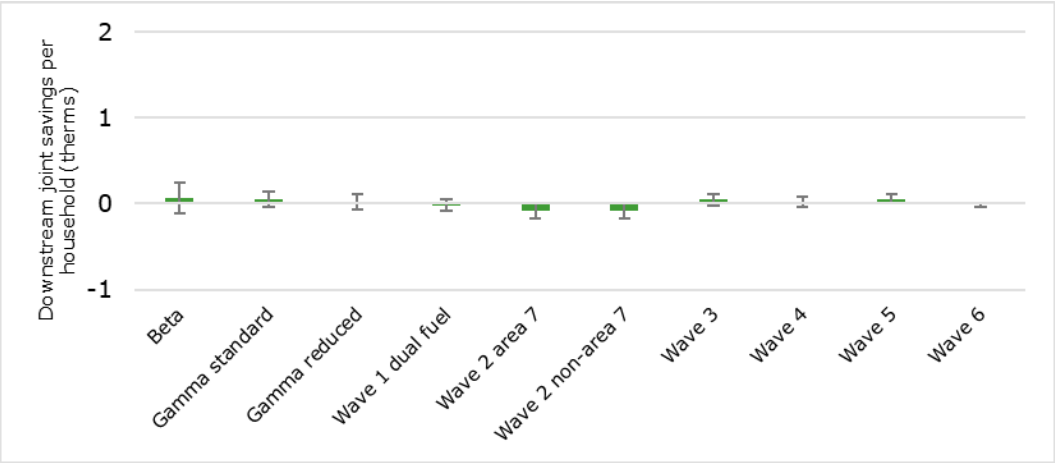
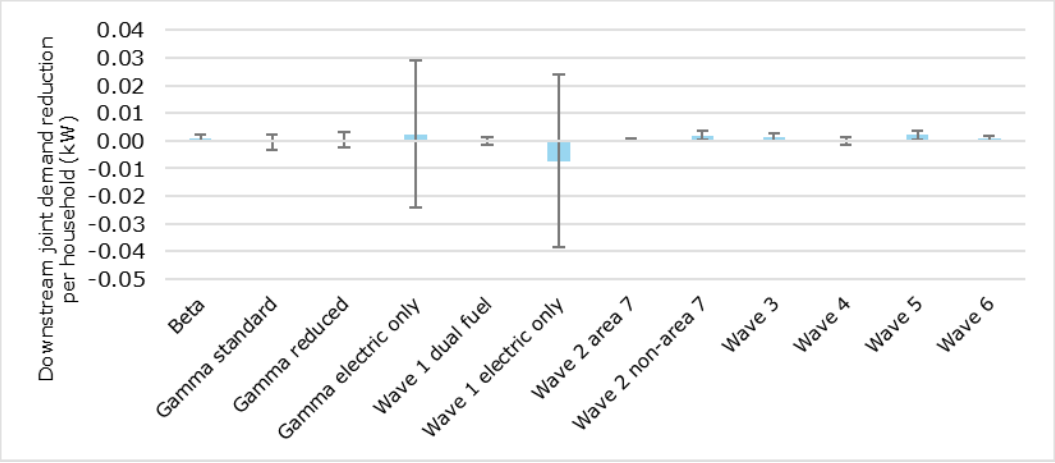


Figure 5-4. PG&E gas downstream joint savings per household per year



The issue of potential double counting also applies to demand impacts to the extent that HER programs successfully motivate increased uptake in other energy efficiency programs and those programs claim demand savings. DNV GL calculated joint savings that are attributed to downstream rebated measures by using deemed demand values contained in downstream rebate tracking data and only by using those measures installed prior to July 27, 2016, the first day of the most common heat wave in 2016. Figure 5-5 shows the per-household downstream kW savings per household.

Figure 5-5. PG&E downstream joint peak demand reduction per household per year



Together these figures indicate the presence of limited joint savings from increased uptake of downstream rebate program due to HER among the treatment group in 2016.

Table 5-2 summarizes the total downstream joint savings for PG&E HER participants. In total, PG&E HER participants generated 4,285 MWh, 82,266 therms, and 1.3 MW of downstream rebate savings due to HER.

Table 5-2. Total PG&E downstream joint savings by wave

Wave	Electric (kWh)	Gas (therms)	Peak Demand (kW)
Beta	307,241	2,831	45.4
Gamma standard	0	2,364	0.0
Gamma reduced	44,883	1,286	25.5
Gamma electric only	0		57.4
Wave 1 dual fuel	985,208	0	0.0
Wave 1 electric only	0		0.0
Wave 2 area 7	213,585	0	23.4
Wave 2 non-area 7	1,475,728	0	460.2
Wave 3	673,617	7,486	207.1
Wave 4	8,875	2,658	0.0
Wave 5	714,148	8,944	356.9
Wave 6	164,193	0	230.9

5.3 Joint savings: upstream programs

Upstream joint savings are like downstream joint savings, except that upstream savings are not tracked at the customer level. PG&E upstream savings still represent a source of savings that the HER program could potentially double count. Unlike tracked programs, it is not possible to directly compare all treatment and control group member activity. This makes it more challenging to determine if the HER program increases savings in upstream programs.

The alternative to the downstream census-level approach is to do a comparison of treatment and control group uptake of the upstream program measures on a sample basis. This approach also takes advantage of the RCT experimental design that provides the structure to produce an un-biased estimate of upstream savings. In 2017, DNV GL conducted an online survey to assess uptake of upstream measures (specifically, CFLs and LEDs) due to HER. The surveys included samples of treatment and control customers from the PG&E HER program.

Table 8-9 in Appendix D presents the uplift of CFL and LEDs for each of PG&E's experimental waves. The results show seven of PG&E's HER waves had CFL bulb uplifts ranging from 0.02 to 1.09 bulbs. In addition, 6 of PG&E's HER waves had 0.16 to 1.95 excess LED bulb purchase due to HER. No adjustments due to upstream joint savings are applied to waves with negative uplift.

Table 5-3 shows the kWh joint savings estimates per household. The total upstream joint savings per household range from 10.2 kWh to 0.5 kWh. HER program savings are adjusted downwards by the upstream joint savings amounts for these waves. Only wave 4 had no upstream joint savings that can be attributed to HER uplift. No adjustments due to upstream joint savings are applied to program savings for this wave.

The replacement of inefficient lighting measures with efficient lamps is associated with an increase in heating load due to lower heat emissions from CFLs and LEDs. These interactive effects translate to a gas penalty that would have been double counted by HER. Table 5-4 gives total interactive therm effects by wave. Negative numbers are subtracted from unadjusted gas savings to remove the gas penalty associated with the removal of electric joint savings from upstream programs.

Table 5-3. PG&E upstream joint savings per household per year

Wave	Upstream Joint Savings per Household per Year				
	Electric (kWh)			Interactive Effects (therms)	Peak Demand (kW)
	CFL	LED	Total		
Beta	9.0	0.7	9.7	-0.3	<0.1
Gamma standard	8.4	0.3	8.7	-0.3	<0.1
Gamma reduced	8.1	0.8	8.9	-0.3	<0.1
Gamma electric only	7.6	2.6	10.2	NA	<0.1
Wave 1 dual fuel	6.9	3.1	9.9	-0.3	<0.1
Wave 1 electric only	7.3	2.0	9.3	NA	<0.1
Wave 2 area 7	1.3	0.5	1.8	-0.1	<0.1
Wave 2 non-area 7	0.7	2.5	3.2	-0.1	<0.1
Wave 3	0.9	0.9	1.8	-0.1	<0.1
Wave 4	-0.2	0.1	0.0	0.0	0
Wave 5	0.3	0.1	0.5	0.0	<0.1
Wave 6	0.3	0.2	0.5	0.0	<0.1

Overall, total upstream joint savings for program year 2016 are 6214 MWh and 0.4 MW (Table 5-4).

Table 5-4. PG&E total upstream joint savings

Wave	Total Upstream Joint Savings		
	Electric (kWh)	Interactive Effects (therms)	Peak Demand (kW)
Beta	408,910	-11,997	21.0
Gamma standard	425,691	-12,464	22.5
Gamma reduced	434,062	-12,747	23.3
Gamma electric only	249,687	NA	14.2
Wave 1 dual fuel	2,515,203	-70,737	153.0
Wave 1 electric only	218,673	NA	12.6
Wave 2 area 7	109,990	-3,538	7.8
Wave 2 non-area 7	734,561	-20,709	55.0
Wave 3	278,229	-8,035	20.1
Wave 4	0	-832	0
Wave 5	77,244	-2,114	6.7
Wave 6	115,973	-2,670	10.4

5.4 Demand savings estimates

Peak demand savings estimates are based on peak period (heat wave) definitions. The period that defines peak demand conditions used to estimate peak demand reductions is presented in section 5.4.1. Peak demand reductions for PG&E's HER waves are presented in section 5.4.2.

5.4.1 Heat waves

Using hourly temperature data from weather stations across PG&E's service territory, DNV GL identified heat wave periods for the summers of 2011 – 2016. The 3-day heatwave in 2016 fell on July 27 – July 29.

Table 5-5 shows the 3-day heatwaves based on DEER definition for the pre- and post-period of the HER participants.

Table 5-5. PG&E DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2016 Post-Period
Beta	6/20/2011	-	6/22/2011	7/27/2016 - 7/29/2016
Gamma standard	6/20/2011	-	6/22/2011	
Gamma reduced	6/20/2011	-	6/22/2011	
Gamma electric only	6/20/2011	-	6/22/2011	
Wave 1 dual fuel	6/20/2011	-	6/22/2011	
Wave 1 electric only	6/20/2011	-	6/22/2011	
Wave 2 area 7	8/13/2012	-	8/15/2012	
Wave 2 non-area 7	8/13/2012	-	8/15/2012	
Wave 3	8/13/2012	-	8/15/2012	
Wave 4	7/1/2013	-	7/3/2013	
Wave 5	7/30/2014	-	8/1/2014	
Wave 6	7/30/2014	-	8/1/2014	

5.4.2 Peak demand reductions

Peak demand savings are calculated using a difference-in-differences modeling framework. This approach involves identifying the peak period during the pre-period in addition to the peak period during the program year being evaluated. A difference-in-differences approach is a more appropriate method for controlling for pre-existing differences in demand between the treatment and the control groups.

Figure 5-6 shows unadjusted peak demand reductions per household by wave along with their confidence intervals. The Beta wave produced the highest amount of kW savings, but all waves produced statistically significant savings.

Figure 5-6. PG&E unadjusted peak demand reduction per household per year

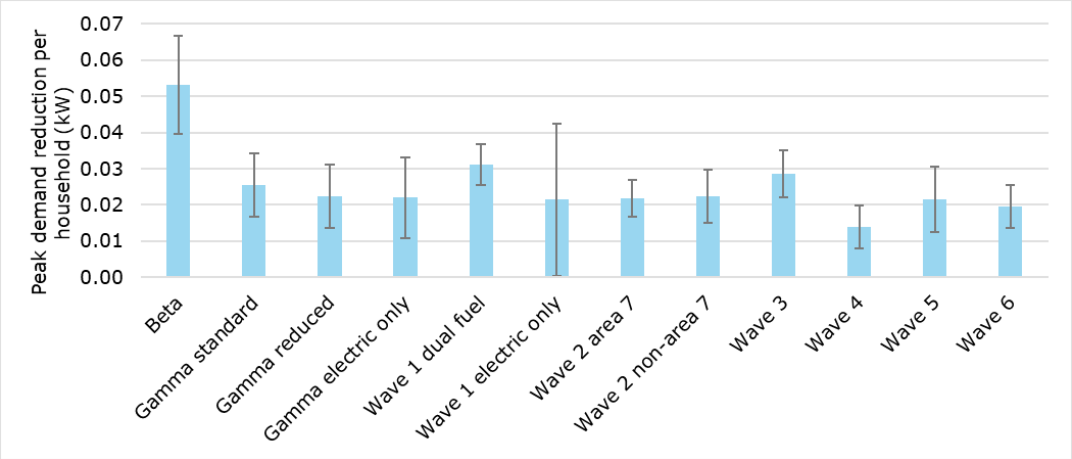


Table 5-6. shows total unadjusted peak demand reductions per wave. In total, PG&E HER participants saved 35 MW during the program year 2016.

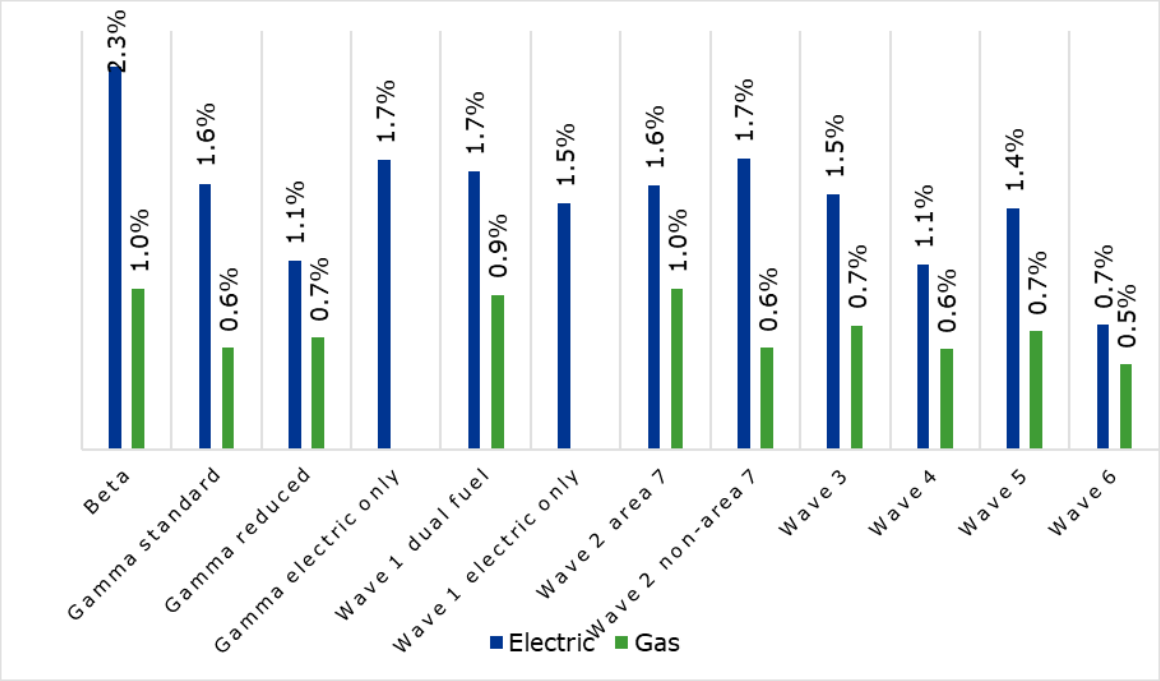
Table 5-6. PG&E total unadjusted peak demand reduction

Wave	Active Accounts during Peak Period (July 27 - July 29, 2016)	Total Peak Reduction (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Beta	42,381	2,249.7	1,678.3	2,821.1
Gamma standard	48,688	1,240.6	813.4	1,667.8
Gamma reduced	48,671	1,086.7	659.6	1,513.7
Gamma electric only	24,351	535.2	262.2	808.2
Wave 1 dual fuel	252,717	7,879.6	6,440.4	9,318.8
Wave 1 electric only	23,525	503.6	10.8	996.3
Wave 2 area 7	60,105	1,304.5	997.7	1,611.2
Wave 2 non-area 7	230,635	5,158.5	3,478.6	6,838.5
Wave 3	158,682	4,523.8	3,494.4	5,553.3
Wave 4	138,905	1,920.8	1,106.5	2,735.2
Wave 5	162,323	3,486.8	2,018.1	4,955.4
Wave 6	260,868	5,103.2	3,543.6	6,662.7

5.5 Total program savings

DNV GL determines total program results based by combining household savings and the number of treatment households in each of PG&E's HER waves. Adjusted household electric and gas savings as a percent of baseline use range from 1% to 2% for electric and 0.5% to 1% for gas (Figure 5-7). Electric savings are in the range of findings for behavioral programs have typically saved 1% to 3% of energy use. Gas savings are lower than electric savings, probably indicating that gas consumption has elements that are less amenable to behavioral changes. More details on per household and total savings by wave can be found in Table 8-13 and Table 8-14 in Appendix E.

Figure 5-7. PG&E percent electric and gas savings by wave



PG&E's HER residential customers saved a total of 138,381 MWh, 4,049, 741 therms and 33.2 MW in program year 2016. These findings are summarized in Table 5-7. and Figure 8-2 at the program level. Total adjusted values reflect savings that can be directly attributed only to HER.

Table 5-7. PG&E total savings for the 2016 HER programs

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	148,536,255
Joint Downstream	4,587,479
Joint Upstream	5,568,224
Adjusted	138,380,552
Gas (therms)	
Unadjusted	3,929,466
Joint Downstream	25,569
Joint Upstream	-145,844
Adjusted	4,049,741
Peak Demand (kW)	
Unadjusted	34,993
Joint Downstream	1,407
Joint Upstream	347
Adjusted	33,240

6 SCE IMPACT RESULTS

6.1 Unadjusted kWh savings estimates

Figure 6-1 shows the unadjusted electric savings per household for the legacy wave (Opower 2) along with the new waves (Opower 3, and 4). The savings for Opower 2 and 3 cover 1 year, but Opower 4's savings cover only 9 months.

Opower 4 had been in the field less than a full year in 2016 and has measured per household savings that are the lowest. For the remaining two waves, savings are greater for the Opower wave (3) whose baseline use is higher. Opower 4 savings are expected to increase in the coming years.

Figure 6-1. SCE unadjusted electric savings per household per year

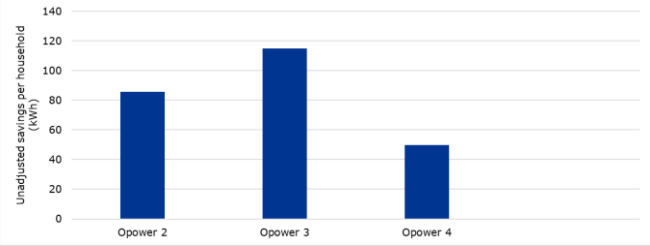


Table 6-1 presents unadjusted savings as a percent of baseline use. Percent savings for SCE's HER waves are about 1% and reflect outcomes that are typical for HER programs.

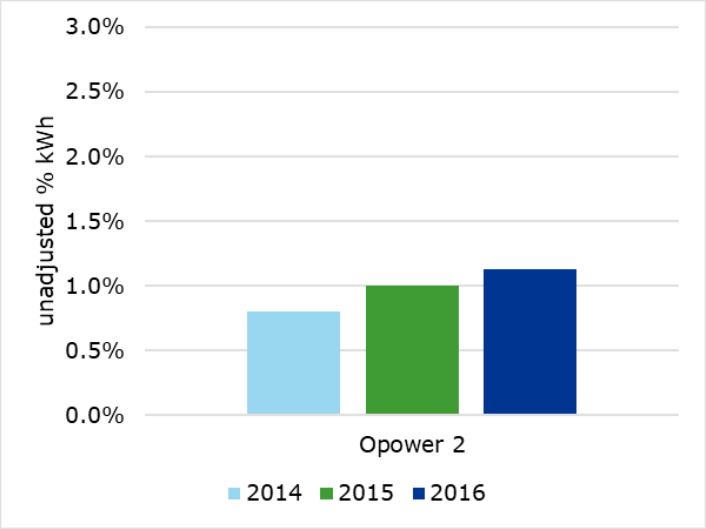
Table 6-1. SCE unadjusted electric savings

Wave	Baseline Consumption	Average Treatment Participants	Unadjusted Savings				
			Per Household per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Opower 2	7,624	65,233	86	5,597,174	4,461,912	6,732,435	1.1%
Opower 3	8,752	152,617	115	17,537,032	15,280,003	19,794,061	1.3%
Opower 4	9,981	247,982	50	12,329,354	7,778,687	16,880,021	0.5%

Note: The average number of treatment participants are reported as a reference point for the size of the wave only. DNV GL calculated total unadjusted savings using monthly treatment counts, not the annual number of treatment participants.

Among SCE's HER waves, Opower 2 has been in the field the longest. Its savings over time are still trending upwards (Figure 6-2). Increasing trends in savings for SCE's HER waves are expected in the coming few program cycles.

Figure 6-2. SCE Opower 2 unadjusted electric percent savings over time



6.2 Joint savings: downstream programs

Downstream joint savings are identified by comparing savings of the treatment and control groups from downstream program installations. These savings from measure installations build up over time in the post-treatment period. If the HER program motivates increased participation in other SCE programs, the treatment group downstream savings will accrue faster than the control group. The difference in savings between the treatment and control groups represents the savings jointly attributable to both the HER program and other downstream programs.

Figure 6-3 and Figure 6-4 provide the estimates of average joint electric and peak demand savings per customer in kWh and kW, respectively. The first figure indicates that HER has encouraged notable joint downstream kWh savings for Opower 2, but not for the rest of SCE's HER waves in 2016. The second figure indicates downstream kW savings for Opower 2 and Opower 3.

Figure 6-3. SCE electric downstream joint savings per household per year

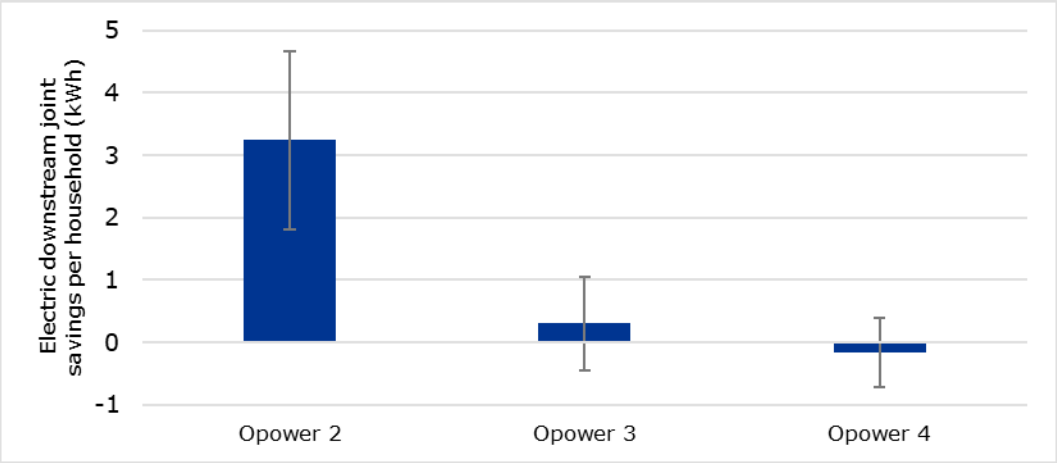


Figure 6-4. SCE downstream joint peak demand reduction per household per year

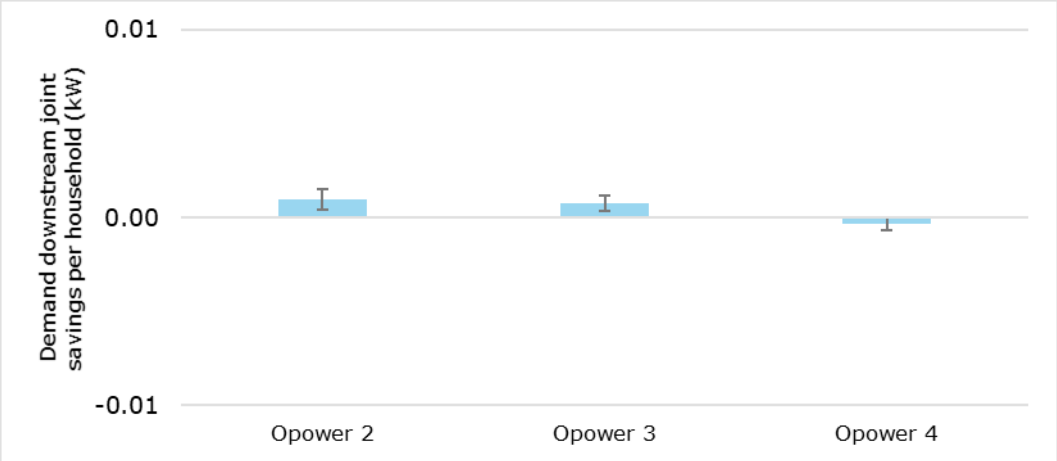


Table 6-2 provides total downstream joint savings by wave. SCE HER treatment groups had 257 MWh and 0.2 MW of peak demand joint savings in 2016 motivated by the HER program.

Table 6-2. Total SCE downstream joint savings by wave

Wave	Electric (kWh)	Peak Demand (kW)
Opower 2	211,046	61.0
Opower 3	45,999	118.2
Opower 4	0	0

6.3 Joint savings: upstream programs

Upstream joint savings are like downstream joint savings, except that upstream savings are not tracked at the customer level. SCE upstream savings still represent a source of savings that the HER program could potentially double count. Unlike tracked programs, it is not possible to directly compare all treatment and control group member activity. This makes it more challenging to determine if the HER program does increase savings in upstream programs.

The alternative to the downstream census-level approach is to do a comparison of treatment and control group uptake of the upstream program measures on a sample basis. This approach also takes advantage of the RCT experimental design that provides the structure to produce an un-biased estimate of upstream savings. In 2017, DNV GL conducted an online survey to assess uptake of upstream measures (specifically, CFLs and LEDs) due to HER. The surveys included samples of treatment and control customers from the SCE HER program.

Table 8-10 in Appendix D presents the uplift of CFL and LEDs for each of SCE's experimental waves. The results show there were uplifts of 1.09 and 0.57 CFLs for Opower 2 and Opower 3, and 1.22 of LEDs for Opower 4 and of less than 0.2 of LEDs for Opower 2 and Opower 5. The rest of the waves had negative bulb uplift indicating that the control group purchased and installed more efficient bulbs than the treatment group.

Table 6-3 shows the kWh joint savings estimates per household. The total upstream joint savings per household are 9.7 kWh per household for Opower 2 and 4.9 for Opower 3. The upstream joint savings per

household for Opower 4 is negative, which indicates that the control group purchased and installed more bulbs than the treatment group. No adjustments due to upstream joint savings are applied to program savings for this wave.

Table 6-3. SCE upstream joint savings per household per year

Wave	Upstream Joint Savings per Household			
	Electric (kWh)			Peak Demand (kW)
	CFL	LED	Total	
Opower 2	8.9	0.8	9.7	<0.1
Opower 3	5.3	-0.4	4.9	<0.1
Opower 4	-4.6	1.4	0.0	0.0

Overall, total program joint savings due to participation in upstream program are 1377 MWh and 0.1 MW program year 2016 (Table 6-4).

Table 6-4. SCE total upstream joint savings

Wave	Total Upstream Joint Savings	
	Electric (kWh)	Peak Demand (kW)
Opower 2	633,851	45.6
Opower 3	743,063	47.0
Opower 4	0	0

6.4 Demand savings estimates

The heat wave definitions, based on DEER criteria, used to estimate peak demand reduction from the HER program are discussed in section 6.4.1. Section 6.4.2 provides estimates of peak demand reduction for SCE's 2016 HER program.

6.4.1 Heat waves

DNV GL identified the 2016 heat waves using weather data from NOAA that contained hourly temperatures from weather stations across the SCE service territory from 2013 – 2016. The three-day heat wave for 2016 fell on July 20 – July 22 (Table 6-5).

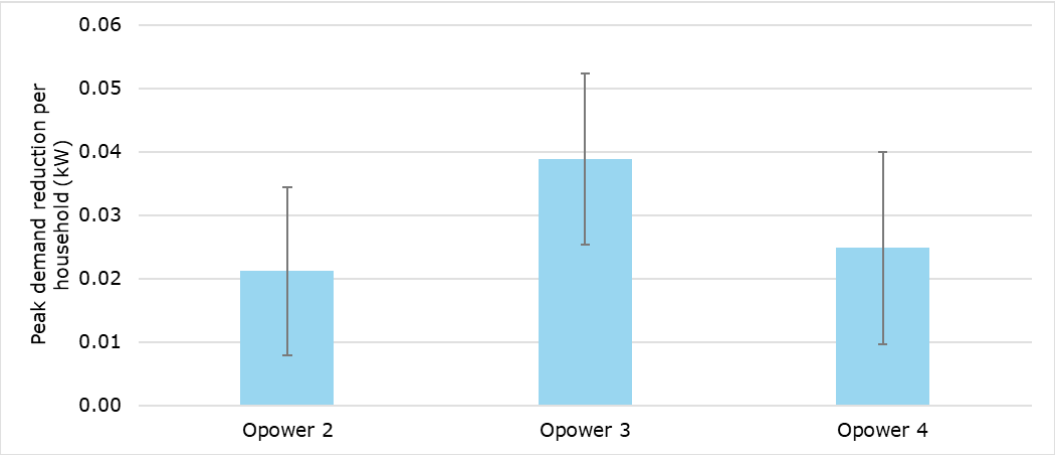
Table 6-5. SCE DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2016 Post-Period
Opower 2	9/4/2013	-	9/6/2013	7/20/2016 - 7/22/2016
Opower 3	9/15/2014	-	9/17/2014	
Opower 4	9/8/2015	-	9/10/2015	

6.4.2 Peak demand reductions

All waves produced statistically significant per-household kW savings. However, these savings are a small fraction of a kWh. For instance, Opower 3's estimated peak demand reduction amounted to 0.04 kW while Opower 4's estimated peak demand reduction per household totaled 0.02 kW (Figure 6-5).

Figure 6-5. SCE unadjusted peak demand reduction per household per year



The estimated peak demand reductions per household for SCE HER waves are used to compute total peak demand reduction. In program year 2016, SCE HER participants generated 14 MW of savings (Table 6-6).

Table 6-6. SCE total unadjusted peak demand reduction

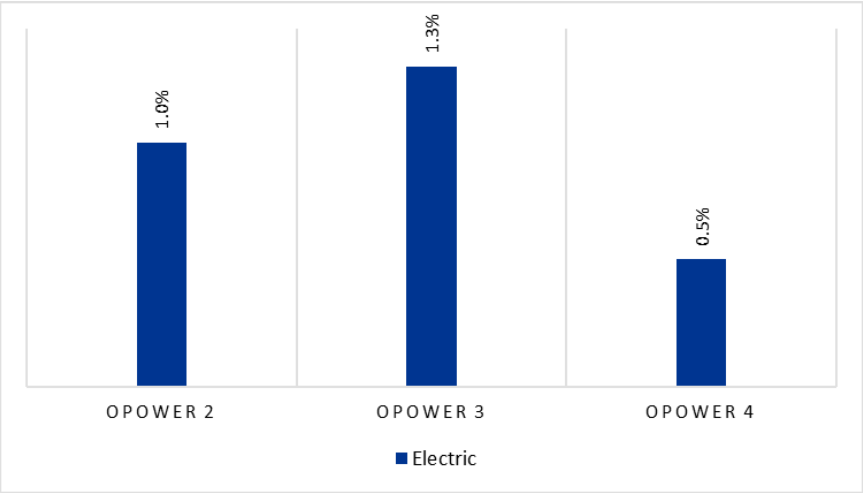
Wave	Active Accounts during Peak Period (July 20 - 22, 2016)	Total Peak Reduction (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Opower 2	65,092	1,377	515	2,239
Opower 3	152,416	5,914	3,862	7,966
Opower 4	252,011	6,264	2,446	10,082

6.5 Total Program Savings

Total HER savings in 2016 are based on total savings by wave. Total wave level savings reflect savings per household and the number of people that received HER in each wave. Further, program level totals reflect adjustment for any uplift in downstream and upstream programs.

This section presents adjusted program level savings. Figure 6-6 presents adjusted electric savings per household as a percent of baseline conditions. Electric savings from SCE's HER program produced about 1% savings per household. Opower 4 value reflects savings for less than 1 year. Like California's other HER programs, these findings are in line with savings that are achieved from such behavioral programs.

Figure 6-6. SCE percent electric savings by wave



Overall, SCE HER participants saved 33,830 MWh and 13 MW in 2016 (Table 6-7 and Figure 8-3). Estimated peak demand savings by wave can be found in Table 8-15 and Table 8-16.

Table 6-7. SCE total savings for the 2016 HER programs

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	35,463,560
Joint Downstream	257,044
Joint Upstream	1,376,914
Adjusted	33,829,601
Peak Demand (kW)	
Unadjusted	13,555
Joint Downstream	179
Joint Upstream	93
Adjusted	13,283

7 CONCLUSIONS AND RECOMMENDATIONS

The HER program impact evaluation results indicate that savings in program year 2016 are either higher than or in line with program year 2015 evaluated savings. The HER program continues to generate significant savings and contributes a high share of total residential energy efficiency portfolio savings. Tests indicate that the sample design adheres to RCT standards and the balanced sample design enables full program attribution for estimated savings.

> The sound experimental design of the HER program and the significant savings realized by each PA year after year support the continued inclusion of HERs as a key tool in the residential EE program arsenal.

An examination of electric savings over time compared to gas savings reveal that percent savings for electric are consistently higher than gas over time. Gas savings remain relatively lower and consistent over time. One possible explanation for this difference is that gas use is tied to essential end-uses such as cooking and heating and hence customers have relatively less potential for gas reductions based on behavioral changes. Electric savings link to essential end-uses like lighting and cooling and also some non-essential ones such as entertainment and pool usage, which could explain the relatively higher magnitude of savings.

First-year electric savings achieved by more recent waves are notably lower than those that were achieved by the Beta wave. Factors outside the program's influence contributing to this include an increased number of electronic devices in the home and electrification trends such as heat pumps, heat pump water heaters, and electric vehicles.

As households continue to increase electricity consumption due to electrification, the HER program, with its proven ability to deliver electric savings, will become an even more important program in the residential energy efficiency portfolio. The HER program should continue to provide information on ways for customers to achieve electric savings.

8 APPENDICES

8.1 Appendix AA Gross and Net Lifecycle Savings

Gross and net lifecycle savings will be presented in the final report.

Gross Lifecycle Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	133,672	138,381	1.04	0.0%	1.04
PGE	**Total**	**133,672**	**138,381**	**1.04**	**0.0%**	**1.04**
SCE	HER Opower Wave 2	4,234	4,752	1.12	0.0%	1.12
SCE	HER Opower Wave 3	14,574	16,748	1.15	0.0%	1.15
SCE	HER Opower Wave 4	11,571	12,329	1.07	0.0%	1.07
SCE	**Total**	**30,378**	**33,830**	**1.11**	**0.0%**	**1.11**
SDGE	2016 HER	0	26,316			
SDGE	**Total**	**0**	**26,316**			
	Statewide	***164,049***	***198,526***	***1.21***	***0.0%***	***1.21***

Net Lifecycle Savings (MWh)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	133,672	138,381	1.04	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**133,672**	**138,381**	**1.04**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	4,234	4,752	1.12	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 3	14,574	16,748	1.15	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 4	11,571	12,329	1.07	0.0%	1.00	1.00	1.00	1.00
SCE	**Total**	**30,378**	**33,830**	**1.11**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SDGE	2016 HER	0	26,316				1.00		1.00
SDGE	**Total**	**0**	**26,316**				**1.00**		**1.00**
	Statewide	***164,049***	***198,526***	***1.21***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

Gross Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	23.3	33.2	1.43	0.0%	1.43
PGE	**Total**	**23.3**	**33.2**	**1.43**	**0.0%**	**1.43**
SCE	HER Opower Wave 2	0.9	1.3	1.46	0.0%	1.46
SCE	HER Opower Wave 3	3.1	5.7	1.83	0.0%	1.83
SCE	HER Opower Wave 4	3.5	6.3	1.81	0.0%	1.81
SCE	**Total**	**7.5**	**13.3**	**1.78**	**0.0%**	**1.78**
SDGE	2016 HER	0.0	6.8			
SDGE	**Total**	**0.0**	**6.8**			
	Statewide	***30.8***	***53.3***	***1.73***	***0.0%***	***1.73***

Net Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	23.3	33.2	1.43	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**23.3**	**33.2**	**1.43**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	0.9	1.3	1.46	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 3	3.1	5.7	1.83	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 4	3.5	6.3	1.81	0.0%	1.00	1.00	1.00	1.00
SCE	**Total**	**7.5**	**13.3**	**1.78**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SDGE	2016 HER	0.0	6.8				1.00		1.00
SDGE	**Total**	**0.0**	**6.8**				**1.00**		**1.00**
	Statewide	***30.8***	***53.3***	***1.73***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

Gross Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	4,006	4,050	1.01	0.0%	1.01
PGE	**Total**	**4,006**	**4,050**	**1.01**	**0.0%**	**1.01**
SCE	HER Opower Wave 2	0	0			
SCE	HER Opower Wave 3	0	0			
SCE	HER Opower Wave 4	0	0			
SCE	**Total**	**0**	**0**			
SDGE	2016 HER	0	757			
SDGE	**Total**	**0**	**757**			
	Statewide	***4,006***	***4,807***	***1.20***	***0.0%***	***1.20***

Net Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	4,006	4,050	1.01	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**4,006**	**4,050**	**1.01**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	0	0						
SCE	HER Opower Wave 3	0	0						
SCE	HER Opower Wave 4	0	0						
SCE	**Total**	**0**	**0**						
SDGE	2016 HER	0	757				1.00		1.00
SDGE	**Total**	**0**	**757**				**1.00**		**1.00**
	Statewide	***4,006***	***4,807***	***1.20***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

Gross First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	133,672	138,381	1.04	0.0%	1.04
PGE	**Total**	**133,672**	**138,381**	**1.04**	**0.0%**	**1.04**
SCE	HER Opower Wave 2	4,234	4,752	1.12	0.0%	1.12
SCE	HER Opower Wave 3	14,574	16,748	1.15	0.0%	1.15
SCE	HER Opower Wave 4	11,571	12,329	1.07	0.0%	1.07
SCE	**Total**	**30,378**	**33,830**	**1.11**	**0.0%**	**1.11**
SDGE	2016 HER	0	26,316			
SDGE	**Total**	**0**	**26,316**			
	Statewide	***164,049***	***198,526***	***1.21***	***0.0%***	***1.21***

Net First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	133,672	138,381	1.04	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**133,672**	**138,381**	**1.04**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	4,234	4,752	1.12	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 3	14,574	16,748	1.15	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 4	11,571	12,329	1.07	0.0%	1.00	1.00	1.00	1.00
SCE	**Total**	**30,378**	**33,830**	**1.11**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SDGE	2016 HER	0	26,316				1.00		1.00
SDGE	**Total**	**0**	**26,316**				**1.00**		**1.00**
	Statewide	***164,049***	***198,526***	***1.21***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

Gross First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	23.3	33.2	1.43	0.0%	1.43
PGE	**Total**	**23.3**	**33.2**	**1.43**	**0.0%**	**1.43**
SCE	HER Opower Wave 2	0.9	1.3	1.46	0.0%	1.46
SCE	HER Opower Wave 3	3.1	5.7	1.83	0.0%	1.83
SCE	HER Opower Wave 4	3.5	6.3	1.81	0.0%	1.81
SCE	**Total**	**7.5**	**13.3**	**1.78**	**0.0%**	**1.78**
SDGE	2016 HER	0.0	6.8			
SDGE	**Total**	**0.0**	**6.8**			
	Statewide	***30.8***	***53.3***	***1.73***	***0.0%***	***1.73***

Net First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	23.3	33.2	1.43	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**23.3**	**33.2**	**1.43**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	0.9	1.3	1.46	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 3	3.1	5.7	1.83	0.0%	1.00	1.00	1.00	1.00
SCE	HER Opower Wave 4	3.5	6.3	1.81	0.0%	1.00	1.00	1.00	1.00
SCE	**Total**	**7.5**	**13.3**	**1.78**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SDGE	2016 HER	0.0	6.8				1.00		1.00
SDGE	**Total**	**0.0**	**6.8**				**1.00**		**1.00**
	Statewide	***30.8***	***53.3***	***1.73***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

Gross First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	2016 HER	4,006	4,050	1.01	0.0%	1.01
PGE	**Total**	**4,006**	**4,050**	**1.01**	**0.0%**	**1.01**
SCE	HER Opower Wave 2	0	0			
SCE	HER Opower Wave 3	0	0			
SCE	HER Opower Wave 4	0	0			
SCE	**Total**	**0**	**0**			
SDGE	2016 HER	0	757			
SDGE	**Total**	**0**	**757**			
	Statewide	***4,006***	***4,807***	***1.20***	***0.0%***	***1.20***

Net First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	2016 HER	4,006	4,050	1.01	0.0%	1.00	1.00	1.00	1.00
PGE	**Total**	**4,006**	**4,050**	**1.01**	**0.0%**	**1.00**	**1.00**	**1.00**	**1.00**
SCE	HER Opower Wave 2	0	0						
SCE	HER Opower Wave 3	0	0						
SCE	HER Opower Wave 4	0	0						
SCE	**Total**	**0**	**0**						
SDGE	2016 HER	0	757				1.00		1.00
SDGE	**Total**	**0**	**757**				**1.00**		**1.00**
	Statewide	***4,006***	***4,807***	***1.20***	***0.0%***	***1.00***	***1.00***	***1.00***	***1.00***

8.2 Appendix AB Per Unit (Quantity) Gross and Net Energy Savings

Per unit (quantity) gross and net energy savings will be presented in the final report.

Per Unit (Quantity) Gross Energy Savings (kWh)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	2016 HER	0	0.0%	0.0%	1.0	1.0	1.0	1.0
SCE	HER Opower Wave 2	0	0.0%	0.0%	1.0	4,752,277.1	4,752,277.1	4,752,277.1
SCE	HER Opower Wave 3	0	0.0%	0.0%	1.0	16,747,970.4	16,747,970.4	16,747,970.4
SCE	HER Opower Wave 4	0	0.0%	0.0%	1.0	12,329,353.9	12,329,353.9	12,329,353.9
SDGE	2016 HER	0	100.0%	0.0%	1.0	26,316,256.8	26,316,256.8	26,316,256.8

Per Unit (Quantity) Gross Energy Savings (Therms)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	2016 HER	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 2	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 3	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 4	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SDGE	2016 HER	0	100.0%	0.0%	1.0	757,093.4	757,093.4	757,093.4

Per Unit (Quantity) Net Energy Savings (kWh)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	2016 HER	0	0.0%	0.0%	1.0	1.0	1.0	1.0
SCE	HER Opower Wave 2	0	0.0%	0.0%	1.0	4,752,277.1	4,752,277.1	4,752,277.1
SCE	HER Opower Wave 3	0	0.0%	0.0%	1.0	16,747,970.4	16,747,970.4	16,747,970.4
SCE	HER Opower Wave 4	0	0.0%	0.0%	1.0	12,329,353.9	12,329,353.9	12,329,353.9
SDGE	2016 HER	0	100.0%	0.0%	1.0	26,316,256.8	26,316,256.8	26,316,256.8

Per Unit (Quantity) Net Energy Savings (Therms)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	2016 HER	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 2	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 3	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER Opower Wave 4	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SDGE	2016 HER	0	100.0%	0.0%	1.0	757,093.4	757,093.4	757,093.4

8.3 Appendix AC Recommendations

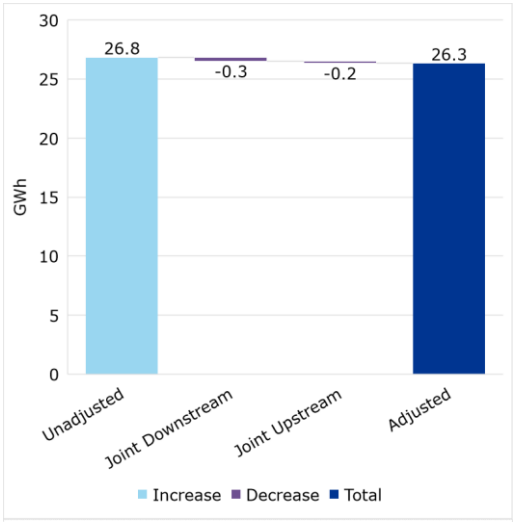
Table 8-1. Home Energy Report PY 2016 Recommendations

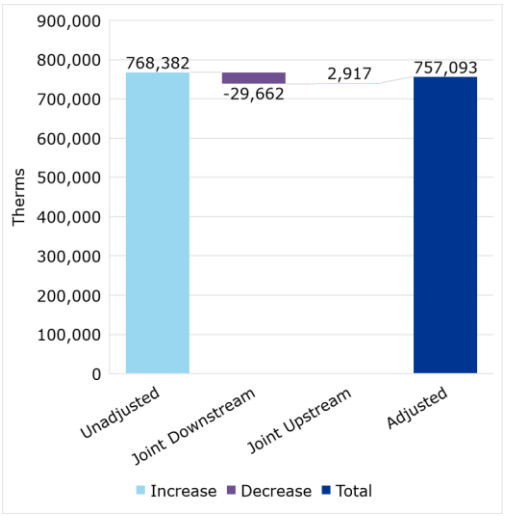
Study ID	Study Type	Study Title/Program	Study Manager
CALMAC ID: CPU0190.01	Impact Evaluation	Home Energy Reports Impact Evaluation PY 2016 (Residential)	CPUC Energy Division
Recommendations (Recipients - All IOUs)	**Summary of Findings**	**Additional Supporting Information**	**Best Practice / Recommendations**
1	An examination of electric savings over time compared to gas savings reveal that percent savings for electric are consistently higher than gas over time.	Sections 4.1 and 5.1	As households continue to increase electricity consumption due to electrification, the HER program, with its proven ability to deliver electric savings, will become an even more important program in the residential energy efficiency portfolio. The HER program should continue to provide information on ways for customers to achieve electric savings.

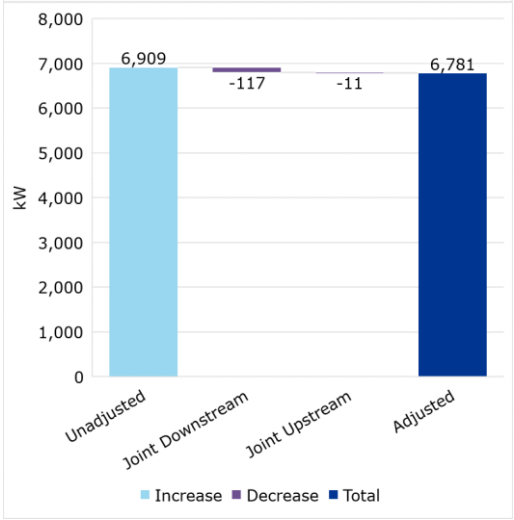
8.4 Appendix A Total savings at a glance

Figure 8-1 is a visual indication of the total SDG&E HER program savings. Negative joint savings values indicate the amount of tracked downstream and untracked upstream savings that are removed from measured program savings to obtain net total net savings for the HER program.

Figure 8-1. SDG&E total savings for the 2016 HER programs

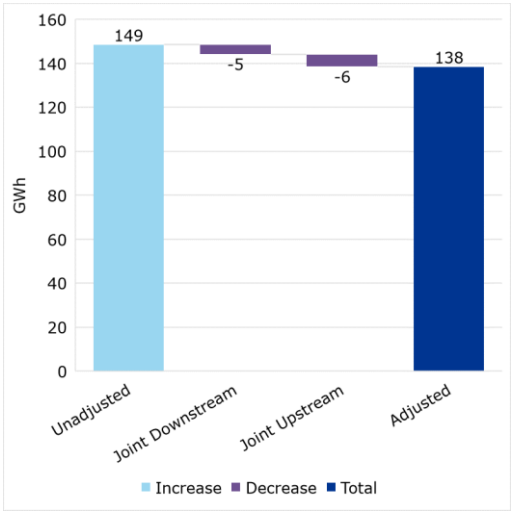


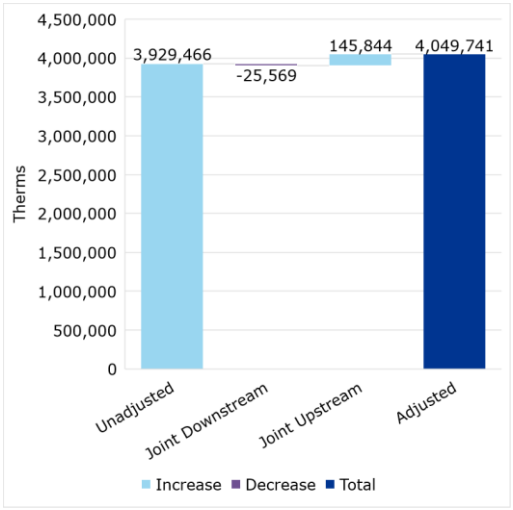


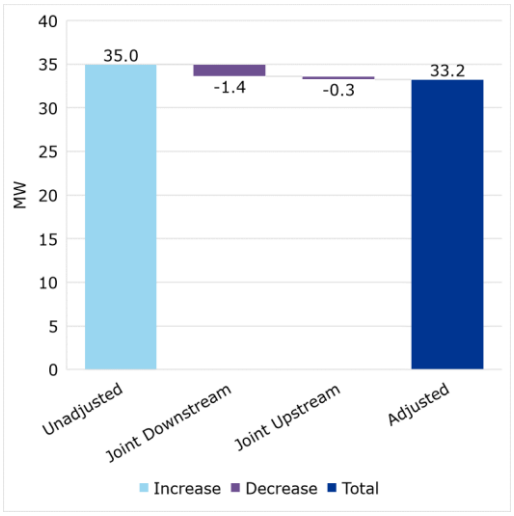


PG&E's program level total savings and tracked downstream and untracked upstream adjustments are illustrated in Figure 8-2.

Figure 8-2. PG&E total savings for the 2016 HER programs

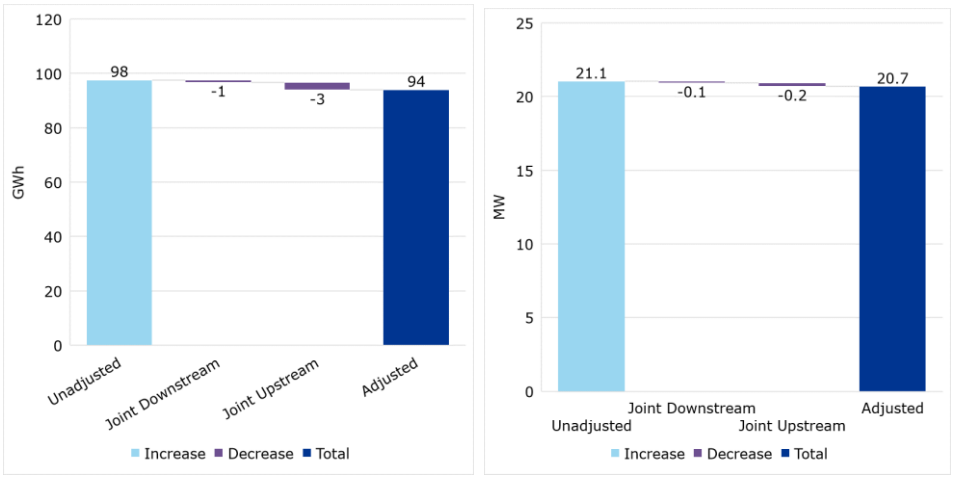






SCE's program level total savings and tracked downstream and untracked upstream adjustments are illustrated in Figure 8-3.

Figure 8-3. SCE total savings for the 2016 HER programs



8.5 Appendix B HER program waves and population counts

The section provides participant rosters with starting counts for each experimental wave of each PA. The disposition for SDG&E's HER waves is presented in Table 8-2. A total of close to 565,000 SDG&E residential customers have received home energy reports since the start of the program in 2011. At the end of 2016, close to 448,000 (79%) of the original recipients remain in the program.

Table 8-2. SDG&E disposition

Sample	Treatment	Control
Opower 1		
Original sample	19,977	19,909
Move-outs	6,110	6,092
Active customers, Jan. 2016	13,867	13,817
Active customers, Dec. 2016	13,087	13,013
Opower 2 Low Income		
Original sample	26,018	7,074
Move-outs	5,851	1,647
Active customers, Jan. 2016	20,167	5,427
Active customers, Dec. 2016	17,597	4,697
Opower 2 Non-Low Income		
Original sample	57,175	15,850
Move-outs	13,365	3,769
Active customers, Jan. 2016	43,810	12,081
Active customers, Dec. 2016	38,353	10,539
Opower 3 Expansion Digital		
Original sample	265,902	24,687
Move-outs	1,697	162
Active customers, Jan. 2016	264,205	24,525
Active customers, Dec. 2016	206,984	19,185
Opower 3 Expansion Paper		
Original sample	195,670	24,697
Move-outs	632	78
Active customers, Jan. 2016	195,038	24,619
Active customers, Dec. 2016	172,299	21,759

Table 8-3 provides a disposition of PG&E's HER program participants. This report presents the energy use impact of home energy reports from PG&E's 12 experimental waves that are underway. The table provides the name, starting treatment and control household counts, and dates for each wave. Since the start of the program, close to 2.0 million of PG&E's residential customers have received home energy reports. Earlier waves have lost notable number of customers in treatment due to move-outs. By the end of 2016, 1.4 million (70% of the original) of PG&E's residential customers were receiving the reports.

Table 8-3. PG&E disposition

Sample	Treatment	Control
Beta		
Original sample	59,994	59,994
Move-outs	16,411	16,350
Active customers, Jan. 2016	43,583	43,644
Active customers, Dec. 2016	41,304	41,458

Sample	Treatment	Control
Gamma standard		
Original sample	72,287	72,292
Move-outs	22,039	22,070
Active customers, Jan. 2016	50,248	50,222
Active customers, Dec. 2016	47,243	47,310
Gamma reduced		
Original sample	72,286	See Gamma standard
Move-outs	21,991	
Active customers, Jan. 2016	50,295	
Active customers, Dec. 2016	47,362	
Gamma electric only		
Original sample	44,985	44,992
Move-outs	19,474	19,661
Active customers, Jan. 2016	25,511	25,331
Active customers, Dec. 2016	23,350	23,270
Wave 1 dual fuel		
Original sample	360,200	89,993
Move-outs	99,597	24,747
Active customers, Jan. 2016	260,603	65,246
Active customers, Dec. 2016	245,985	61,630
Wave 1 electric only		
Original sample	39,787	9,999
Move-outs	15,288	3,841
Active customers, Jan. 2016	24,499	6,158
Active customers, Dec. 2016	22,722	5,703
Wave 2 area 7		
Original sample	80,051	50,071
Move-outs	18,039	11,325
Active customers, Jan. 2016	62,012	38,746
Active customers, Dec. 2016	58,491	36,512
Wave 2 non-area 7		
Original sample	305,280	47,712
Move-outs	67,720	10,599
Active customers, Jan. 2016	237,560	37,113
Active customers, Dec. 2016	224,665	35,117
Wave 3		
Original sample	224,996	75,020
Move-outs	59,306	19,889
Active customers, Jan. 2016	165,690	55,131
Active customers, Dec. 2016	153,112	50,848
Wave 4		
Original sample	200,000	75,000
Move-outs	52,583	19,768
Active customers, Jan. 2016	147,417	55,232
Active customers, Dec. 2016	132,181	49,566
Wave 5		
Original sample	210,000	50,200
Move-outs	38,262	9,218
Active customers, Jan. 2016	171,738	40,982
Active customers, Dec. 2016	155,129	36,980

Sample	Treatment	Control
Wave 6		
Original sample	312,000	50,000
Move-outs	25,444	4,161
Active customers, Jan. 2016	286,556	45,839
Active customers, Dec. 2016	242,476	38,648

Table 8-4 presents the disposition of the HER population for SCE. SCE has 3 active HER experimental waves underway. A total of close to half a million SCE residential customers have received home energy report since the start of the program. Close to 9 out 10 (89% of the original) households received the reports by the end of due to customer attrition (moveouts).

Table 8-4. SCE disposition

Sample	Treatment	Control
Opower 2		
Original sample	75,000	75,000
Move-outs	8,260	8,170
Active customers, Jan. 2016	66,740	66,830
Active customers, Dec. 2016	63,721	63,750
Opower 3		
Original sample	164,800	50,315
Move-outs	6,964	2,167
Active customers, Jan. 2016	157,836	48,148
Active customers, Dec. 2016	147,887	44,946
Opower 4		
Original sample	265,650	37,107
Move-outs	5,062	748
Active customers, Jan. 2016	260,588	36,359
Active customers, Dec. 2016	239,902	33,434

8.6 Appendix C Data quality

Table 8-5, Table 8-6, and Table 8-7 present the quality of the data used in the gross savings models. These summaries are for treatment and control households active in 2016. The summary for zero reads, negative reads, and missing reads look across fuel type when the household is dual fuel, meaning that both the gas and electric consumption data would need to have the issue in the bill period in order for it to be flagged. Extreme reads are flagged if both or either the electric or gas read is extreme. A household may have zero reads, negative reads, missing reads, and extreme reads, so the percentages may be greater than 100%.

Table 8-5. SDG&E data quality summary

Data Issues	Treatment	Control
Opower 1		
Zero Reads	15.6%	15.4%
Negative Reads	9.0%	9.0%
Missing Reads	0.0%	0.0%
Extreme Reads	4.1%	5.0%
No Issues	80.1%	79.3%
Opower 2 Low Income		
Zero Reads	2.3%	2.1%
Negative Reads	0.5%	0.4%
Missing Reads	0.0%	0.0%
Extreme Reads	0.2%	0.2%
No Issues	97.6%	97.7%
Opower 2 Non-Low Income		
Zero Reads	5.1%	4.8%
Negative Reads	1.9%	1.8%
Missing Reads	0.0%	0.0%
Extreme Reads	0.2%	0.2%
No Issues	94.5%	94.9%
Opower 3 Expansion Digital		
Zero Reads	2.2%	2.2%
Negative Reads	0.0%	0.0%
Missing Reads	0.0%	0.0%
Extreme Reads	0.0%	0.0%
No Issues	97.7%	97.8%
Opower 3 Expansion Paper		
Zero Reads	8.4%	8.4%
Negative Reads	0.1%	0.0%
Missing Reads	0.0%	0.0%
Extreme Reads	2.5%	2.5%
No Issues	89.3%	89.2%

Table 8-6. PG&E data quality summary

Data Issues	Treatment	Control
Beta		
Zero Reads	0.16%	0.12%
Negative Reads	6.48%	6.30%
Missing Reads	0.00%	0.01%
Extreme Reads	2.79%	3.01%
No Issues	90.71%	90.72%

Data Issues	Treatment	Control
Gamma standard		
Zero Reads	0.28%	0.25%
Negative Reads	5.53%	5.36%
Missing Reads	0.02%	0.02%
Extreme Reads	0.81%	0.79%
No Issues	93.43%	93.64%
Gamma reduced		
Zero Reads	0.25%	See Gamma standard
Negative Reads	5.37%	
Missing Reads	0.01%	
Extreme Reads	0.75%	
No Issues	93.68%	
Gamma electric only		
Zero Reads	0.40%	0.40%
Negative Reads	2.89%	2.75%
Missing Reads	0.01%	0.00%
Extreme Reads	0.93%	1.08%
No Issues	95.83%	95.82%
Wave 1 dual fuel		
Zero Reads	0.11%	0.10%
Negative Reads	4.64%	4.51%
Missing Reads	0.01%	0.01%
Extreme Reads	0.57%	0.59%
No Issues	94.71%	94.83%
Wave 1 electric only		
Zero Reads	0.15%	0.18%
Negative Reads	6.58%	6.60%
Missing Reads	0.02%	0.00%
Extreme Reads	1.47%	1.36%
No Issues	91.98%	92.06%
Wave 2 area 7		
Zero Reads	0.15%	0.17%
Negative Reads	2.42%	2.33%
Missing Reads	0.00%	0.01%
Extreme Reads	0.91%	0.93%
No Issues	96.55%	96.59%
Wave 2 non-area 7		
Zero Reads	0.13%	0.15%
Negative Reads	4.34%	4.03%
Missing Reads	0.01%	0.01%
Extreme Reads	0.60%	0.63%
No Issues	94.99%	95.26%
Wave 3		
Zero Reads	0.13%	0.10%
Negative Reads	3.77%	3.72%
Missing Reads	0.01%	0.01%
Extreme Reads	0.79%	0.91%
No Issues	95.34%	95.31%
Wave 4		
Zero Reads	0.19%	0.20%
Negative Reads	2.71%	2.68%
Missing Reads	0.02%	0.01%
Extreme Reads	0.76%	0.75%
No Issues	96.37%	96.41%

Data Issues	Treatment	Control
Wave 5		
Zero Reads	0.08%	0.09%
Negative Reads	5.06%	4.86%
Missing Reads	0.01%	0.00%
Extreme Reads	2.42%	2.37%
No Issues	92.55%	92.79%
Wave 6		
Zero Reads	0.12%	0.11%
Negative Reads	1.34%	1.20%
Missing Reads	0.02%	0.02%
Extreme Reads	0.54%	0.58%
No Issues	97.99%	98.10%

Table 8-7. SCE data quality summary

Data Issues	Treatment	Control
Opower 2		
Zero Reads	0.48%	0.46%
Negative Reads	0.00%	0.00%
Missing Reads	0.00%	0.00%
Extreme Reads	0.46%	0.44%
No Issues	99.06%	99.10%
Opower 3		
Zero Reads	0.21%	0.21%
Negative Reads	0.00%	0.00%
Missing Reads	0.00%	0.00%
Extreme Reads	0.99%	0.94%
No Issues	98.80%	98.86%
Opower 4		
Zero Reads	0.40%	0.40%
Negative Reads	0.00%	0.00%
Missing Reads	0.00%	0.00%
Extreme Reads	4.79%	4.85%
No Issues	94.81%	94.75%

8.7 Appendix D Key inputs for upstream joint savings calculations

Table 8-8, Table 8-9. PG&E upstream joint savings calculation inputs, and present the input assumptions used in the upstream joint savings calculations by program administrator. For SDG&E and PG&E, the excess lamps due to HER were applied based on the year of the wave rather than calendar year until 2015. This means, if a wave began in July 2011, it would use the year 1 excess lamps from July 2011 through June 2012 and then use the year 2 excess lamps for the next wave year until calendar year 2015. Beginning in 2015, excess lamps due to HER was also calculated separately for each wave. All other inputs are not wave specific. In 2014, with the introduction of LEDs, the uplift was split between LEDs and CFLs using the fraction of lamps in 2014 from the 2014 TRC HER lighting overlap study. See section 3.5 for further information about how DNV GL calculated upstream joint savings.

Table 8-8. SDG&E upstream joint savings calculation inputs

Assumptions	CFL	LED	Source
Opower 1 excess lamps due to HER			
Year 1	0.95	NA	2013 PG&E in-home survey
Year 2	0.40	NA	Interpolated from PG&E ad PSE values (DNV GL)
Year 3	0.15	NA	2013 PSE HER phone survey (DNV GL)
Year 4	0.08	0.08	2013 PSE HER phone survey (DNV GL)
2015	0.32	0.20	2015 Online Survey (DNV GL, 2017)
2016	-0.30	0.74	2016-2017 Online Survey (DNV GL, 2019)
Opower 2 excess lamps due to HER			
2015	-0.07	-0.65	2015 Online Survey (DNV GL, 2017)
2016	-0.04	-0.03	2016-2017 Online Survey (DNV GL, 2019)
Opower 3 excess lamps due to HER			
2016	-0.35	-1.32	2016-2017 Online Survey (DNV GL, 2019)
Rebated sales fraction			
2011	0.57	NA	2014 TRC HER lighting overlap study
2012	0.68	NA	2014 TRC HER lighting overlap study
2013	0.4	NA	2014 TRC HER lighting overlap study
2014	0.18	0.32	2014 TRC HER lighting overlap study
2015 - 2016	0.2	0.31	2015 TRC HER lighting overlap study
Net-to-gross			
2011 - 2012	0.61	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	0.30	0.32	2013-14 ULP Evaluation (DNV GL, 2016)
2016	0.80	0.41	2015 ULP Evaluation (DNV GL, 2017)
Installation rate			
2011 - 2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	1.00	1.00	N/A
Years lamps have been installed in 2016			
2011 - 2015	1.00	1.00	
2016	0.54	0.54	
Annual electric savings per lamp			
2011	23.3	Not available	2010-12 ULP Evaluation (DNV GL, 2014)
2012	22.6	Not available	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	17.9	21.8	2014 TRC HER lighting overlap study
2016	16.4	27.4	2015 ULP Evaluation (DNV GL, 2017)
Gas interactive effects per lamp			
2011 - 2014	-0.4	-0.4	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	-1.0	-0.5	2015 ULP Evaluation (DNV GL, 2017)

Delta Watts			
2011 - 2016	29.8	34.8	2015 ULP Evaluation (DNV GL, 2017)
Peak Coincidence Factor			
2011 - 2016	0.0	0.1	2015 ULP Evaluation (DNV GL, 2017)
Proportion of lamps in place during peak			
2011 - 2015	1.0	1.0	
2016	0.7	0.7	

Table 8-9. PG&E upstream joint savings calculation inputs

Assumptions	CFL	LED	Source
Excess lamps due to HER prior to 2015 for all waves			
Year 1	0.95	0.95	2012 PG&E in-home survey
Year 2	0.4	0.4	Interpolated from PG&E and PSE values (DNV GL)
Year 3	0.15	0.15	2013 PSE HER phone survey (DNV GL)
Year 4	0.08	0.08	2014 PSE HER phone survey (DNV GL)
Beta excess lamps due to HER			
2015	-0.17	0.09	2015 Online Survey (DNV GL, 2017)
2016	0.02	0.36	2016-2017 Online Survey (DNV GL, 2019)
Gamma standard excess lamps due to HER			
2015	0.17	0.33	2015 Online Survey (DNV GL, 2017)
2016	1.09	-0.53	2016-2017 Online Survey (DNV GL, 2019)
Gamma reduced excess lamps due to HER			
2015	0.01	0.44	2015 Online Survey (DNV GL, 2017)
2016	0.41	-0.27	2016-2017 Online Survey (DNV GL, 2019)
Gamma electric only excess lamps due to HER			
2015	-0.07	0.23	2015 Online Survey (DNV GL, 2017)
2016	-0.69	1.95	2016-2017 Online Survey (DNV GL, 2019)
Wave 1 dual fuel excess lamps due to HER			
2015	0.02	0.71	2015 Online Survey (DNV GL, 2017)
2016	0.13	1.32	2016-2017 Online Survey (DNV GL, 2019)
Wave 1 electric only excess lamps due to HER			
2015	0.61	0.24	2015 Online Survey (DNV GL, 2017)
2016	0.13	1.32	2016-2017 Online Survey (DNV GL, 2019)
Wave 2 area 7 fuel excess lamps due to HER			
2015	0.02	0.51	2015 Online Survey (DNV GL, 2017)
2016	0.40	-0.95	2016-2017 Online Survey (DNV GL, 2019)
Wave 2 non-area 7 excess lamps due to HER			
2015	0.01	0.55	2015 Online Survey (DNV GL, 2017)
2016	-1.14	0.86	2016-2017 Online Survey (DNV GL, 2019)
Wave 3 excess lamps due to HER			
2015	0.09	0.09	2015 Online Survey (DNV GL, 2017)
2016	0.10	0.16	2016-2017 Online Survey (DNV GL, 2019)
Wave 4 excess lamps due to HER			
2015	-0.16	-0.09	2015 Online Survey (DNV GL, 2017)
2016	-0.95	-0.28	2016-2017 Online Survey (DNV GL, 2019)
Wave 5 excess lamps due to HER			
2015	0.00	0.11	2015 Online Survey (DNV GL, 2017)
2016	0.72	-0.28	2016-2017 Online Survey (DNV GL, 2019)
Wave 6 excess lamps due to HER			
2015	0.03	0.29	2015 Online Survey (DNV GL, 2017)
2016	0.74	-0.03	2016-2017 Online Survey (DNV GL, 2019)

Assumptions	CFL	LED	Source
Rebated sales fraction			
2011	0.50	NA	2014 TRC HER lighting overlap study
2012	0.45	NA	2014 TRC HER lighting overlap study
2013	0.16	NA	2014 TRC HER lighting overlap study
2014	0.07	0.21	2014 TRC HER lighting overlap study
2015 - 2016	0.09	0.20	2015 TRC HER lighting overlap study
Net-to-gross			
2011 - 2012	0.63	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	0.31	0.45	2013-14 ULP Evaluation (DNV GL, 2016)
2016	0.47	0.33	2015 ULP Evaluation (DNV GL, 2017)
Installation rate			
2011 - 2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	1.00	1.00	N/A
Years lamps have been installed in 2016			
2011 - 2015	1.00	1.00	
2016	0.54	0.54	
Annual electric savings per lamp (kWh)			
2011	26.80	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2012	26.20	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	23.50	24.80	Program tracking data (DEER 2013-14)
2016	15.95	28.54	2015 ULP Evaluation (DNV GL, 2017)
Gas interactive effects per lamp (therms)			
2011 - 2014	-0.78	-0.71	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	-0.34	-0.63	2015 ULP Evaluation (DNV GL, 2017)
Delta watts			
	25.17	36.67	2015 ULP Evaluation (DNV GL, 2017)
Peak coincidence factor			
	0.05	0.06	2015 ULP Evaluation (DNV GL, 2017)
Proportion of lamps in place during peak			
2011 - 2015	1.00	1.00	
2016	0.57	0.57	

Table 8-10. SCE upstream joint savings calculation inputs

Assumptions	CFL	LED	Source
Opower 2 excess lamps due to HER			
2014	0.68	0.27	2012 PG&E in-home survey multiplied (0.95) by TRC estimate for fraction of CFL bulbs sold in SCE territory (.72) and by the fraction of LED bulbs sold in SCE territory (0.28)
2015	-0.18	0.15	2015 Online Survey (DNV GL, 2017)
2016	1.09	0.23	2016-2017 Online Survey (DNV GL, 2019)
Opower 3 excess lamps due to HER			
2015 - 2016	0.57	-0.22	2016-2017 Online Survey (DNV GL, 2019)
Opower 4 excess lamps due to HER			
2016	-1.07	1.22	2016-2017 Online Survey (DNV GL, 2019)
Rebated sales fraction			
2014	0.4	0.2	2014 TRC HER lighting overlap study
2015 - 2016	0.53	0.23	2015 TRC HER lighting overlap study
Net-to-gross			
2014 - 2015	0.45	0.31	2013-14 ULP Evaluation (DNV GL, 2016)
2016	0.90	0.36	2015 ULP Evaluation (DNV GL, 2017)
Installation rate			
2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	1.00	1.00	N/A

Years lamps have been installed in 2016			
2014 - 2015	1.00	1.00	
2016	0.54	0.54	
Annual electric savings per lamp (kWh)			
2014 - 2015	45.2	19.9	2014 TRC HER lighting overlap study
2016	22.5	34.0	2015 ULP Evaluation (DNV GL, 2017)
Gas interactive effects per lamp (therms)			
2014	-0.7	-0.5	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2016	-2.4	-0.6	2015 ULP Evaluation (DNV GL, 2017)
Delta Watts			
2014 - 2016	29.5	41.5	2015 ULP Evaluation (DNV GL, 2017)
Peak Coincidence Factor			
2014 - 2016	0.1	0.1	2015 ULP Evaluation (DNV GL, 2017)
Proportion of lamps in place during peak			
2014 - 2015	1.0	1.0	
2016	0.6	0.6	

8.8 Appendix E Total program savings by wave

Table 8-11 presents unadjusted and adjusted savings per household for each of SDG&E's HER waves.

Table 8-11. SDG&E per household electric and gas savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Downstream	Joint Upstream	Adjusted	Unadjusted	Adjusted
Electric (kWh)							
Opower 1	8,250	141	6	12	123	1.7%	1.5%
Opower 2 Low Income	5,149	58	1	0	57	1.1%	1.1%
Opower 2 Non-Low Income	4,736	67	<1	0	67	1.4%	1.4%
Opower 3 Expansion Digital	4,701	37	0	0	37	0.8%	0.8%
Opower 3 Expansion Paper	9,673	71	1	0	70	0.7%	0.7%
Gas (therms)							
Opower 1	466	9	0	<1	9	1.8%	1.9%
Opower 2 Low Income	255	<1	<1	0	<1	0.1%	0.1%
Opower 2 Non-Low Income	238	<1	0	0	0	-0.2%	0.0%
Opower 3 Expansion Digital	243	2	0	0	2	0.7%	0.7%
Opower 3 Expansion Paper	369	3	<1	0	3	0.9%	0.9%

Table 8-12 presents the total unadjusted and adjusted savings by wave for SDG&E's HER program.

Table 8-12. SDG&E total savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Opower 1	1,895,673	77,250	166,156	1,652,267
Opower 2 Low Income	1,088,936	20,284	0	1,068,652
Opower 2 Non-Low Income	2,761,026	30,140	0	2,730,886
Opower 3 Expansion Digital	8,227,260	0	0	8,227,260
Opower 3 Expansion Paper	12,847,674	210,483	0	12,637,191
Gas (therms)				
Opower 1	116,301	0	-2,917	119,218
Opower 2 Low Income	5,963	2,272	0	3,691
Opower 2 Non-Low Income	-15,457	0	0	0
Opower 3 Expansion Digital	248,140	0	0	248,140
Opower 3 Expansion Paper	413,434	27,390	0	386,044
Peak Demand (kW)				
Opower 1	442	17	11	415
Opower 2 Low Income	128	7	0	121
Opower 2 Non-Low Income	404	0	0	404
Opower 3 Expansion Digital	1,543	0	0	1,543
Opower 3 Expansion Paper	4,392	93	0	4,299

Table 8-13 summarizes the electric and gas savings per household for each of PG&E HER waves. Adjusted percent savings that account for both downstream and upstream savings are largely the same as the unadjusted percent savings, changing by at most 0.2%. The adjusted savings calculation only considered average joint savings that are positive despite being statistically insignificant, as they provide some evidence of possible double counting.

Table 8-13. PG&E per household electric and gas savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Downstream	Joint Upstream	Adjusted	Unadjusted	Adjusted
Electric (kWh)							
Beta	9,448	233	7	10	216	2.5%	2.3%
Gamma standard	6,613	114	0	9	105	1.7%	1.6%
Gamma reduced	6,613	84	<1	9	74	1.3%	1.1%
Gamma electric only	6,678	125	0	10	115	1.9%	1.7%
Wave 1 dual fuel	6,617	124	4	10	110	1.9%	1.7%
Wave 1 electric only	7,459	119	0	9	110	1.6%	1.5%
Wave 2 area 7	5,748	96	4	2	90	1.7%	1.6%
Wave 2 non-area 7	6,347	120	6	3	110	1.9%	1.7%
Wave 3	6,345	103	4	2	97	1.6%	1.5%
Wave 4	5,803	64	<1	0	64	1.1%	1.1%
Wave 5	8,696	130	4	<1	125	1.5%	1.4%
Wave 6	5,949	46	<1	<1	44	0.8%	0.7%
Gas (therms)							
Beta	657	6	<1	>-1	6	0.9%	1.0%
Gamma standard	382	2	<1	>-1	2	0.6%	0.6%
Gamma reduced	382	2	<1	>-1	3	0.6%	0.7%
Wave 1 dual fuel	392	3	0	>-1	4	0.9%	0.9%
Wave 2 area 7	439	4	0	>-1	4	0.9%	1.0%
Wave 2 non-area 7	401	2	0	>-1	2	0.6%	0.6%
Wave 3	401	3	<1	>-1	3	0.7%	0.7%
Wave 4	369	2	<1	>-1	2	0.6%	0.6%
Wave 5	458	3	<1	>-1	3	0.7%	0.7%
Wave 6	369	2	0	>-1	2	0.5%	0.5%

Table 8-14 summarizes the total savings by wave for PG&E. Negative joint downstream and upstream savings were not deducted except negative upstream savings for gas.

Table 8-14. PG&E total savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Beta	9,880,662	307,241	408,910	9,164,511
Gamma standard	5,551,761	0	425,691	5,126,070
Gamma reduced	4,111,601	44,883	434,062	3,632,656
Gamma electric only	3,059,022	0	249,687	2,809,336
Wave 1 dual fuel	31,323,776	985,208	2,515,203	27,823,365
Wave 1 electric only	2,812,019	0	218,673	2,593,346
Wave 2 area 7	5,771,631	213,585	109,990	5,448,056
Wave 2 non-area 7	27,662,036	1,475,728	734,561	25,451,748
Wave 3	16,333,184	673,617	278,229	15,381,337
Wave 4	8,952,106	8,875	0	8,943,231
Wave 5	21,198,074	714,148	77,244	20,406,682
Wave 6	11,880,382	164,193	115,973	11,600,216
Gas (therms)				
Beta	258,267	2,831	-11,997	267,433
Gamma standard	103,203	2,364	-12,464	113,303
Gamma reduced	113,195	1,286	-12,747	124,657
Wave 1 dual fuel	843,654	0	-70,737	914,391
Wave 2 area 7	250,135	0	-3,538	253,673
Wave 2 non-area 7	544,420	0	-20,709	565,129
Wave 3	475,254	7,486	-8,035	475,803
Wave 4	309,563	2,658	-832	307,737
Wave 5	535,410	8,944	-2,114	528,580
Wave 6	496,365	0	-2,670	499,036
Peak Demand (kW)				
Beta	2,249.7	45.4	21.0	2,183.4
Gamma standard	1,240.6	0.0	22.5	1,218.1
Gamma reduced	1,086.7	25.5	23.3	1,037.8
Gamma electric only	535.2	57.4	14.2	463.6
Wave 1 dual fuel	7,879.6	0.0	153.0	7,726.6
Wave 1 electric only	503.6	0.0	12.6	491.0
Wave 2 area 7	1,304.5	23.4	7.8	1,273.3
Wave 2 non-area 7	5,158.5	460.2	55.0	4,643.3
Wave 3	4,523.8	207.1	20.1	4,296.6
Wave 4	1,920.8	0.0	0	1,920.8
Wave 5	3,486.8	356.9	6.7	3,123.1
Wave 6	5,103.2	230.9	10.4	4,861.8

Table 8-15 summarizes SCE's kWh and kW savings per household by wave.

Table 8-15. SCE per household electric savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Downstream	Joint Upstream	Adjusted	Unadjusted	Adjusted
Opower 2	7,624	86	3	10	73	1.1%	1.0%
Opower 3	8,752	115	<1	5	110	1.3%	1.3%
Opower 4	9,981	50	0	0	50	0.5%	0.5%

Table 8-16 summarizes SCE's total kWh and kW savings by wave.

Table 8-16. SCE total savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Opower 2	5,597,174	211,046	633,851	4,752,277
Opower 3	17,537,032	45,999	743,063	16,747,970
Opower 4	12,329,354	0	0	12,329,354
Peak Demand (kW)				
Opower 2	1,377.1	61.0	45.6	1,271
Opower 3	5,913.9	118.2	47.0	5,749
Opower 4	6,263.7	0	0	6,264

8.10 Appendix F HER savings by PA from 2011 to

Table 8-17. Historical HER kWh and therm savings per household across PAs from 2011 to 2014

Year/ PA	Wave	No. of Treatment Months	Unadjusted kWh Savings per Household	Percent kWh Savings	Unadjusted therms Savings per Household	Percent therms Savings
2011-12						
PG&E	Beta	17	234	1.5%	10	0.9%
	Gamma Dual Standard	14	90	1.1%	3	0.6%
	Gamma Dual Reduced	14	74	0.9%	4	0.6%
	Gamma Electric only	14	111	1.4%	NA	NA
	Wave One Dual	11	77	1.1%	1	0.4%
	Wave One Electric only	11	85	1.1%	NA	NA
SDG&E	Pilot	18	310	2.0%	12	1.5%
2013						
PG&E	Beta	12	221	2.1%	8	1.0%
	Gamma Dual Standard	12	112	1.5%	2	0.5%
	Gamma Dual Reduced	12	101	1.4%	2	0.5%
	Gamma Electric only	12	118	1.7%	NA	NA
	Wave One Dual	12	112	1.5%	3	0.6%
	Wave One Electric only	12	128	1.6%	NA	NA
	Wave Two Area 7	11	52	0.9%	3	0.6%
	Wave Two Not Area 7	11	60	0.9%	3	0.7%
	Wave Three	6	27	0.8%	1	0.6%
SCE	Opower1	12	123	1.2%	NA	NA
SDG&E	Pilot	12	282	2.8%	11	2.0%
2014						
PG&E	Beta	12	222	2.2%	5	0.8%
	Gamma Dual Standard	12	121	1.7%	2	0.6%
	Gamma Dual Reduced	12	99	1.4%	2	0.6%
	Gamma Electric only	12	105	1.5%	NA	NA
	Wave One Dual	12	117	1.7%	3	0.7%
	Wave One Electric only	12	129	1.6%	NA	NA
	Wave Two Area 7	12	92	1.4%	3	0.8%
	Wave Two Not Area 7	12	86	1.5%	3	0.8%
	Wave Three	12	69	1.0%	3	0.8%
	Wave Four	10	37	0.7%	1	0.2%
	Wave Five	3	10	0.4%	1	0.6%
SCE	Opower2	9	52	0.8%	NA	NA
SDG&E	Pilot	12	259	2.6%	8	1.8%
2015						
PG&E	Beta	12	224	2.3%	7.4	1.1%
	Gamma Dual Standard	12	110	1.6%	2.4	0.6%
	Gamma Dual Reduced	12	94	1.4%	2.8	0.7%
	Gamma Electric only	12	128	1.9%	NA	NA
	Wave One Dual	12	121	1.8%	3.6	0.9%
	Wave One Electric only	12	137	1.8%	NA	NA
	Wave Two Area 7	12	97	1.7%	5.2	1.3%
	Wave Two Not Area 7	12	116	1.8%	4	1.0%
	Wave Three	12	102	1.6%	3.4	0.9%
	Wave Four	12	73	1.2%	3.3	0.9%
	Wave Five	12	108	1.2%	2.7	0.6%
	Wave Six	4	9	0.5%	0.7	0.5%
SCE	Opower2	12	77.7	1.0%	NA	NA
SDG&E	Opower 1	12	232	2.4%	8	1.8%
	Opower 2	12	41	0.8%	0	0.1%

Year/ PA	Wave	No. of Treatment Months	Unadjusted kWh Savings per Household	Percent kWh Savings	Unadjusted therms Savings per Household	Percent therms Savings
2016						
PG&E	Beta	12	233	2.5%	6	0.9%
	Gamma Dual Standard	12	114	1.7%	2	0.6%
	Gamma Dual Reduced	12	84	1.3%	2	0.6%
	Gamma Electric only	12	125	1.9%	NA	NA
	Wave One Dual	12	124	1.9%	3	0.9%
	Wave One Electric only	12	119	1.6%	NA	NA
	Wave Two Area 7	12	96	1.7%	4	0.9%
	Wave Two Not Area 7	12	120	1.9%	2	0.6%
	Wave Three	12	103	1.6%	3	0.7%
	Wave Four	12	64	1.1%	2	0.6%
	Wave Five	12	130	1.5%	3	0.7%
	Wave Six	12	46	0.8%	2	0.5%
SCE	Opower 2	12	86	1.1%	NA	NA
	Opower 3	12	115	1.3%	NA	NA
	Opower 4	9	50	0.5%	NA	NA
SDG&E	Opower 1	12	141	1.7%	9	1.8%
	Opower 2 Low Income	12	58	1.1%	<1	0.1%
	Opower 2 Non-Low Income	12	67	1.4%	<1	-0.2%
	Opower 3 Expansion Digital	12	37	0.8%	2	0.7%
	Opower 3 Expansion Paper	12	71	0.7%	3	0.9%