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Impact Evaluation of Home Energy Reports
Residential Sector - Program Year 2018

EM&V Group A

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1 EXECUTIVE SUMMARY

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), Southern California Gas Company (SCG), and San Diego Gas and Electric's (SDG&E) Home Energy Report programs for 2018. The evaluation conducted by DNV GL includes calculated energy and demand savings estimates that the CPUC can use to support PG&E, SCE, SCG, and SDG&E's saving claims for behavioral programs in 2018.

1.1 Background

The residential sector accounts for 17 percent of the state of California's energy consumption. The sector is comprised of more than 14 million single- and multi-family homes that house more than 39 million Californians. California investor-owned utilities (IOUs) account for approximately three quarters of the electricity supply in the state. The California Public Utilities Commission (CPUC) mandates that these IOUs function as program administrators (PA) and offer behavioral programs to motivate residential customers to adopt no- or low-cost energy efficient behaviors. In the Home Energy Report (HER) program, PAs' customers receive home energy reports (HER) that include information about customers' energy consumption, a comparison to energy consumption of similar customers, and customized tips for saving energy. PG&E and SDG&E began sending HER to customers in 2011, while SCE and SCG began their HER programs in 2012 and 2015, respectively.

In designing and implementing a Home Energy Report program, the PAs randomly assign customers into either a **treatment group** that receives the reports or a **control group** that does not receive the reports, such that the customers are alike in all important ways except receiving the reports. Since the program's inception, the IOUs have instituted successive HER treatment groups (waves). As of this evaluation for program year 2018, there are 15 waves for PG&E, 8 waves for SDG&E, 6 waves for SCE, and 6 waves for SCG.

1.2 Research questions and objectives

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

- What are the energy and demand savings for each HER wave?
- How much energy and demand savings are attributable to both downstream (customer receives a rebate/incentive) and upstream (manufacturer receives an incentive) programs as well as HER programs?
- What are the total energy and demand savings for each HER wave at the recipient and program level? What percentage of consumption do these savings represent?
- Did the randomization process produce a balanced sample design for new waves? Was the balance maintained after attrition for existing waves?
- Develop additional insights that will facilitate improved programs and/or improved evaluation in the future.
    - Do energy savings persist over time as treatment continues?
    - What are the hourly load savings shapes from the HER?
    - What happens to energy savings at premises previously occupied by HER treatment participants?

1.3 Study approach

DNV GL evaluated HER for program year 2018 to answer the above research questions. DNV GL addressed questions regarding energy, demand, hourly load savings shapes, and the persistence of HER savings using industry standard best practice methods. These methods involve comparing the energy consumption of treatment and control customers prior to and after treatment customers start receiving the home energy report. This approach enables quantification of the overall impact of the HER program on average energy and demand use of customers who receive the HERs.

In addition, adjustments are made to these measured energy and demand savings, to avoid double-counting savings that may be reported by other energy-efficiency programs.

1.4 Key findings

1.4.1 Total program savings

Unadjusted HER program claimed savings represent substantial percentages of claimed statewide residential program energy efficiency savings. They represent over 80% of first year net kWh savings, 63% of first year net therm savings, and 94% of first year net kW savings. These claims are evaluated and adjusted to remove part of the HER savings claimed by other energy efficiency programs.

In program year 2018, HER programs motivated 1% to 3% savings per recipient and those savings were consistent with the savings achieved by the program in prior years. Table 1-1 shows that the HER programs generated electric, demand, and gas savings of 303,000 MWh, 67 MW, and 11 million therms, respectively, for program year 2018. These are adjusted values that remove the portion of HER savings claimed by other energy efficiency programs.[1]

[1] For example, the installation of additional efficient lighting that is motivated by HER is claimed by lighting programs and needs to be removed from HER program savings. However, lower electricity use from efficient lighting increases gas use due to a reduction in the amount of heat generated from more efficient lighting and is added to HER gas savings. Adjusted gas savings can, thus, be higher than unadjusted values.

Table 1-1. Total HER evaluated program savings for program year 2018

Type of Savings	PG&E	SDG&E	SCE	SCG	Total
Electric (MWh)					
Unadjusted	133,996	50,450	132,583		**317,029**
Adjusted	125,615	49,749	127,895	N/A	**303,259**
Gas (therms)					
Unadjusted	4,591,699	1,183,537		4,717,191	**10,492,427**
Adjusted	4,769,550	1,138,867	N/A	4,712,298	**10,620,715**[2]
Peak Demand (MW)					
Unadjusted	31	9	29		**69**
Adjusted	30	8	29	N/A	**67**

1.4.2 Longitudinal savings trends

DNV GL conducted a trend analysis of HER program savings. Figure 1-1 summarizes the average savings for a HER recipient as a percentage of average household baseline energy consumption for each PA's earliest waves from launch until the current evaluation year. These trends indicate the continuing efficacy of the HER program in delivering consistent savings as the program matures. The figure shows that while electric savings exhibit an initial upward trend followed by a plateau, gas savings do not have any particular trend and are relatively stable over the years.

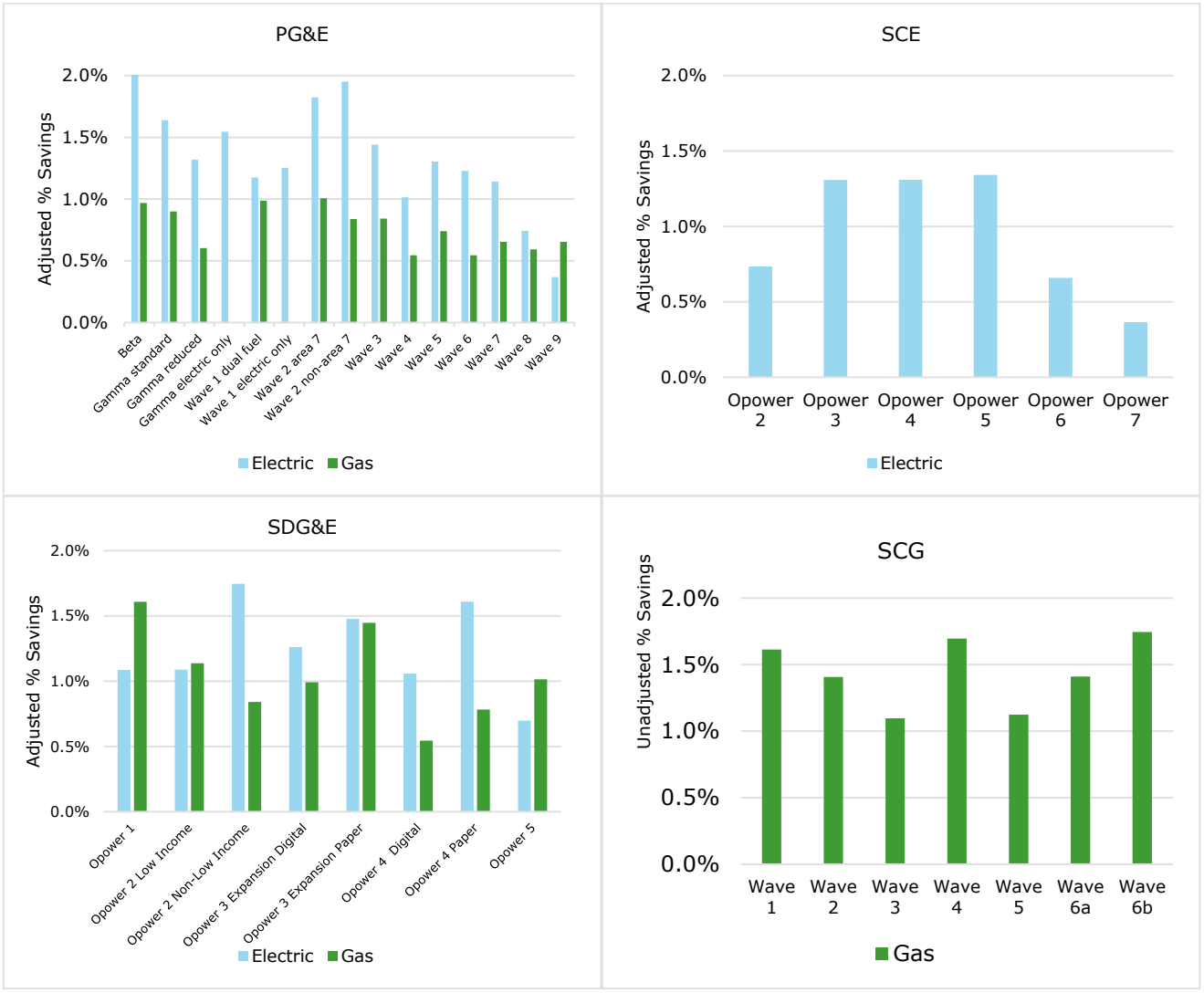
[2] See previous footnote for an explanation of why adjusted gas savings could be higher than unadjusted values.

Figure 1-1. Electric and gas savings trends for early HER waves by PA

1.4.3 Program savings by wave for program year 2018

DNV GL verified significant savings from the HER programs for program year 2018. These results remain consistent with prior evaluations of HER programs. Figure 1-2 illustrates the adjusted first-year percent savings relative to baseline energy consumption for evaluated waves as of program year 2018. Different HER targeting approaches, modes of delivery, and frequency of reports all contributed to the variation seen across PAs.

Figure 1-2. PY 2018 adjusted percent savings by wave



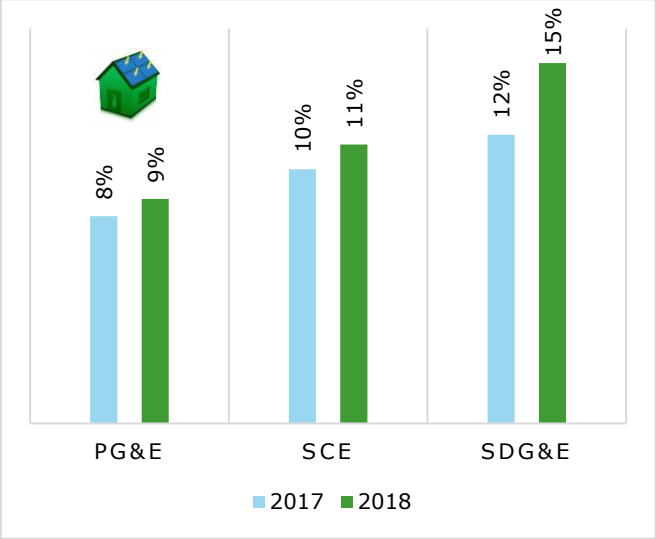
1.4.4 Solar PV adoption

Customer adoption of rooftop solar photovoltaic (PV) is increasing in California. The data used for this evaluation reflect this trend. Solar adoption across all HER customers showed an increase of 1% to 3% for all PAs from 2017 to 2018. For instance, solar adoption among SDG&E's HER customers increased from 12% in 2017 to 15% in 2018 (Figure 1-3).

The increasing trend of solar use carries weight for future HER program evaluations because billing data provide household energy consumption that is net of household self-generation. This increase is currently equally prevalent among HER treatment and control group customers in all PAs. If there are different levels of adoption of solar or installations of differently sized solar panels between treatment and control group customers, the estimated program savings will be biased. For example, if information provided by the HER is causing the HER program participants to adopt differently sized solar panels or have different rates of solar adoption than the control group, the difference in the actual energy consumption between them would vary from the difference if measured using only their utility sourced energy consumption. This would result in HER

treatment effects that are not accurately measured. Thus, it is increasingly important to have data on on-site generation to get clearer visibility into the energy consumption of households to ensure unbiased estimates of HER program savings.

Figure 1-3. Prevalence of rooftop solar among HER customers in 2017 and 2018



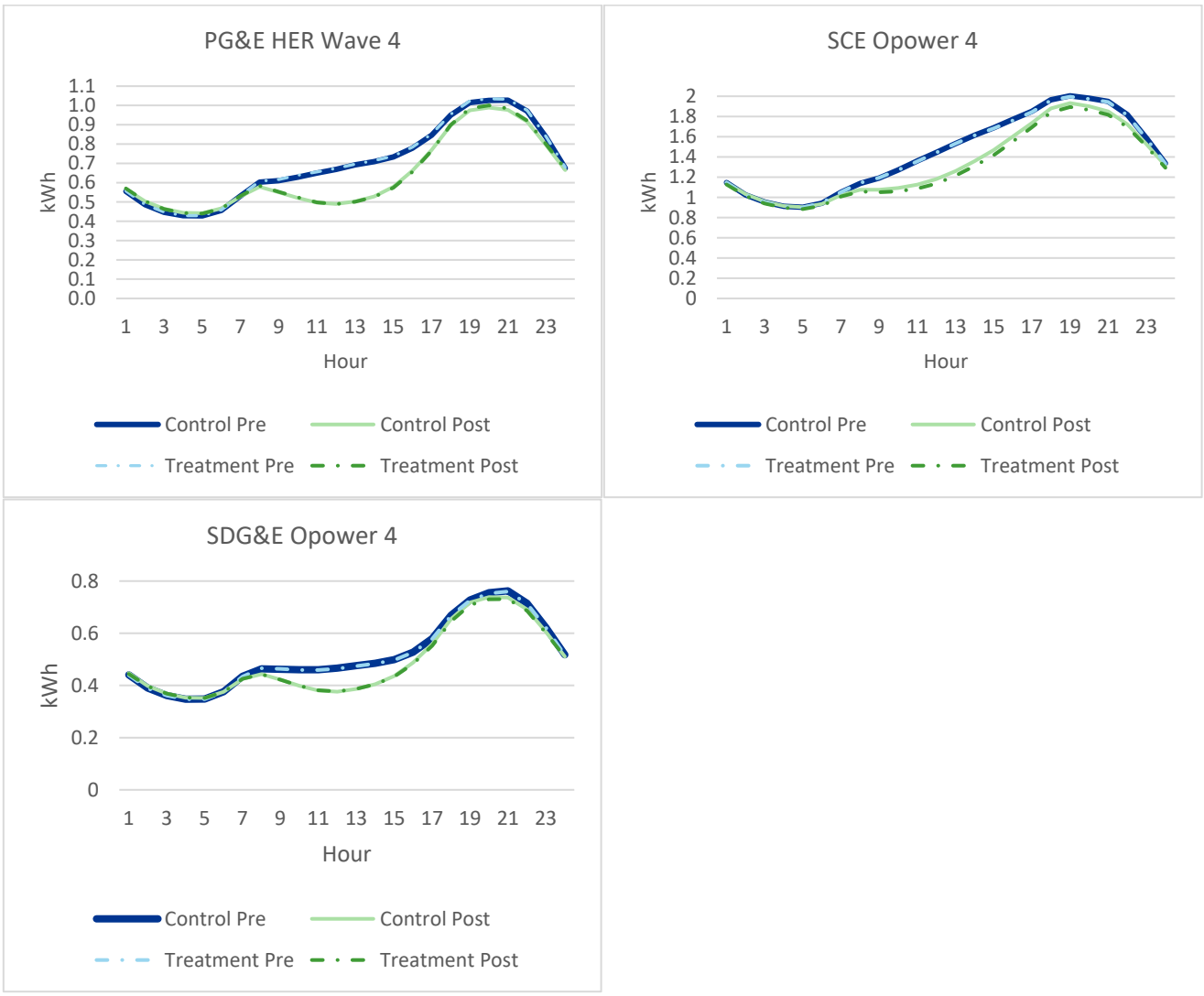
1.4.5 Hourly load shapes

Figure 1-4 below summarizes average pre- and post-period hourly electricity consumption for treatment and control customers for selected HER waves for PG&E, SCE, and SDG&E. The three panels in the figure illustrate the following:

1. There is an overall reduction in average hourly energy consumption from the pre to the post period indicating a downward shift in energy consumption over time for both groups.
2. There is an overall change in load shapes from the pre to the post period (indicating the effect of the increasing presence of behind-the-meter solar – 'duck curve' effect).

These hourly load shapes provide context to interpret findings from the HER load savings shape analyses in the following section.

Figure 1-4. Average hourly pre- and post-period load shapes for treatment and control customers



1.4.6 HER program load savings shapes

Currently, all HER programs use a single load shape[3] for claimed savings and cost effectiveness calculations, and the evaluation also tested this assumption.

DNV GL estimated HER load savings shapes for a single wave from each of the three electric IOUs.[4] These waves were selected based on longer tenure and the high energy consumption customer segment they targeted. DNV GL used data from 10,000 homes randomly chosen from each wave's treatment and control groups.[5] As evidenced in the section above, the randomized control design of the HER program shows that

[3] Current HER load shapes are based on a combination of DEER residential lighting and HVAC load shapes weighted to resemble an empirical load savings shape from a subset of PG&E waves in 2015.

[4] Wave names are listed in Figure 1-4 and Figure 1-5.

[5] Since this is the first undertaking of its type for the HER evaluation and the data requirements were substantial, DNV GL conducted the study using data from a random subset of households from these waves as a proof of concept.

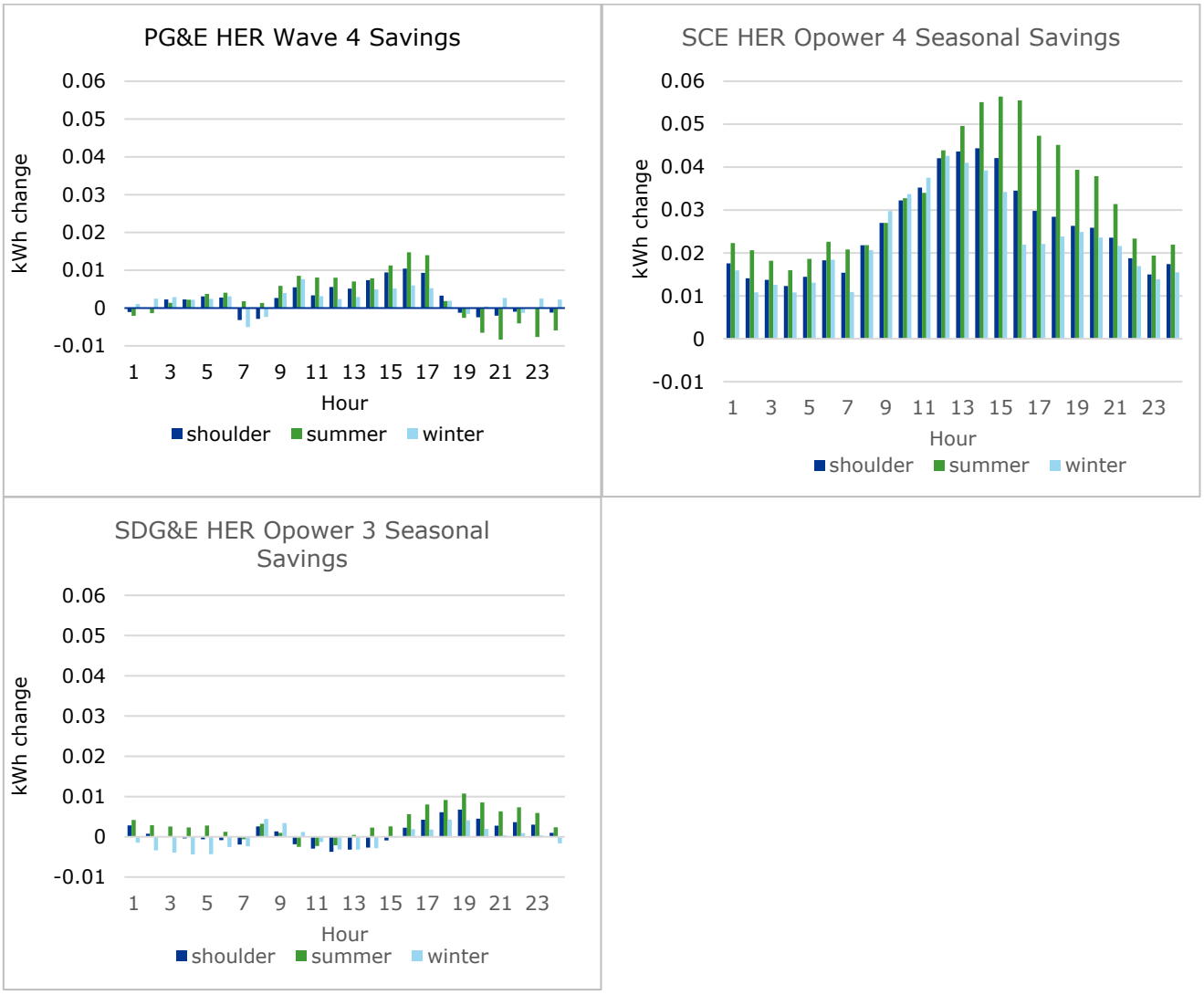
average hourly load for treatment and control groups are well balanced. This provides a sound basis for the load savings shape analysis presented in this section. The load savings shapes are provided in Figure 1-5.

Key findings from the HER programs load savings shape analysis are as follows:

- There is considerable variability in hourly HER program savings by PA, which is different than the current single load-shape assumption
- Since hourly HER program savings have variation by wave, it appears that there is no singular HER load shape that can be applied to all waves

This exploratory analysis indicates that a single HER load savings shapes is unlikely to effectively represent all of the true load savings shapes for these waves. While this analysis covers a subset of customers from selected waves as a proof concept, these findings point to the need for a more comprehensive study of the topic.

Figure 1-5. Average hourly load savings shape by season and PA



1.4.7 Savings persistence

DNV GL investigated if HER induced savings, which might lead to changes in the energy efficiency of the home, persist after a treatment customer moves. As well documented in several independent evaluations including the current one, HER delivers energy savings of 1% to 3%. The question of what happens to these savings when treatment customers move, and the reports stop is explored in the current study.

Based on data from PG&E's HER Wave 3, we find that HER treated homes that change occupancy retain 55% of the estimated savings. For this wave, 0.12 kWh of the 0.22 kWh daily average HER treatment savings persist after treatment customers move and the home energy reports are no longer delivered. The results suggest that the HER program promotes savings, at least in part, by encouraging installation of energy efficient equipment and related home improvements.

1.5 Conclusions and Recommendations

The sound experimental design of the HER program provides accurate and highly precise information on the savings that can be attributed to the HER program.

DNV GL recommends that greater attention be paid to the interaction of on-site solar adoption with the HER programs. It is a reasonable hypothesis that HER reports could affect the subsequent decision to adopt PV or the size of the installation. If this is the case, then HER savings estimates will no longer solely reflect HER savings.

DNV GL recommends continued refinement of the exploratory load savings shape analysis in future evaluation cycles. The HER load shapes built this way offer a way to develop new program load savings shapes for use in cost effectiveness and other avoided cost calculations.

The findings from the exploratory analysis on persistence show that substantial savings endure following occupancy change in treated homes. DNV GL recommends that the persistence analysis be widened to include a more complete set of movers, other waves, fuel type, and IOUs for a more definitive understanding of persistence.

2 INTRODUCTION

2.1 Project description and participation

The residential sector accounts for 17% of California's energy consumption. The sector includes over 14 million single- and multi-family homes that house more than 39 million Californians. California investor-owned utilities (IOUs) account for approximately three quarters of the electricity supply in the state. In 2012 the California Public Utilities Commission (CPUC) directed California program administrators (PA) to offer behavioral programs to at least 5% of households they serve. Further, the CPUC mandated that the programs employ a strategy of comparative energy use that follows an experimental design approach.

Each PA, including Pacific Gas & Electric (PG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), and San Diego Gas & Electric (SDG&E), offers a home energy report (HER) program that complies with the CPUC mandate. These reports contain information about household energy use, including a comparison to similar neighbors' energy use and customized tips for saving energy. HERs can reduce energy consumption by motivating no- and low-cost energy conservation actions and installation of energy efficient measures.

PG&E and SDG&E began offering their HER programs in 2011, while SCE and SCG first offered their programs in 2012 and 2015, respectively. By the end of 2015, these reports constituted the largest residential measure on a kilowatt-hours-saved basis.[6] Each PA introduces new HER waves over time. For new waves the PAs send HERs to recipients from different populations or apply slightly different treatments. Also, PAs introduce new waves as customers in older waves leave the program (attrition). Attrition ranged from 4% to 24% in the 2018 program year. Table 2-1 presents a summary of HER program status for each PA as of 2018.

Table 2-1. HER 2018 program status

PA	Piloted in	Number of waves	Total 2018 residential households	Treatment	Control	Total active accounts in HER program in December 2018[7]
PG&E	August 2011	15	5,688,431	2,387,219	707,242	1,957,678
SCE	December 2012	6	4,424,508	1,912,289	306,158	1,860,622
SCG	November 2015	7	5,668,452	861,040	324,592	918,213
SDG&E	July 2011	8	1,300,634	899,173	158,516	696,590

The current evaluation reflects a few changes in the HER program. PG&E launched Waves 8 and 9 in late 2017 and mid-2018, which are included in the current evaluation. SCE also launched Opower 6 and 7 in the spring and fall, respectively, of 2018 that evaluated in the current cycle. Additionally, DNV GL is evaluating SCG's HER program for the first time in program year 2018. SCG transitioned the HER program from its Advanced Meter Infrastructure (AMI) project to its energy efficiency portfolio at the end of 2017. Currently, SCG administers seven HER waves.

[6] 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

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

2.2 Evaluation objectives

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

- What are the energy and demand savings for each HER wave?
- How much energy and demand savings can both downstream and upstream programs and HER programs jointly claim?
- What are the total (adjusted) energy and demand savings for each HER wave at the recipient and program level? What percentage of consumption do these savings represent?
- Did the randomization process produce a balanced sample design for new waves? Was the 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 both downstream and upstream programs and HER programs jointly claim?
- Do energy savings persist over time as treatment continues?
- What are the hourly load savings shapes from the HER?
- What happens to energy savings at premises previously occupied by HER treatment?

3 METHODOLOGY

3.1 Data sources

Table 3-1 presents a summary of the data sources used in the HER evaluation. These data sources are used to calculate the following types of savings which will be further discussed in the next sections:

- *Unadjusted energy savings*: Total savings achieved without removing savings that may have been claimed by another program if a HER recipient also participates in other programs.
- *Downstream rebate joint savings*: Savings that occur because HER recipients purchase more rebated measures offered through downstream rebate energy efficiency programs than non-recipients. These savings are included in the unadjusted energy savings but were claimed by a downstream rebate program and should be removed from HER savings estimates to avoid double counting.
- *Upstream rebate joint savings*: Savings that occur because HER recipients install more efficient light bulbs rebated through the upstream lighting program than non-recipients. These savings are included in the unadjusted energy savings but were claimed by the upstream lighting rebate program and should be removed from HER savings estimates to avoid double counting.
- *Adjusted energy savings*: HER savings after removing downstream and upstream rebate joint savings.

Table 3-1. Data sources

Data type	Source	Data Includes	Use
Participant list[8]	PAs	• Customer account numbers (service agreement, customer, and premise numbers) • Customers' HER waves and start dates • Additional customer-level information	Used to identify treatment and control households for the evaluation
Monthly billing data	PAs	• Customer account numbers (service agreement, customer, and premise numbers) • Billing cycle start and end dates • Consumption readings • Net metering flags • Read type (i.e., actual meter reading/estimated meter reading).	Used to estimate unadjusted energy savings
Downstream program data	CPUC	• Participant information • Account numbers • Program names • Measures installed • Installation dates • Claimed energy savings	Used to identify HER recipient participation in downstream rebate programs to estimate downstream rebate joint savings and adjusted energy savings
Online survey data	2017 online survey of HER participants conducted by DNV GL[9]	• Quantity of CFL and LED lamps bulbs purchased and installed by HER recipients • Quantity of CFL and LED lamps bulbs purchased and installed by the HER control group	Used to assess HER recipient efficient light bulb purchases and installations to calculate upstream rebate joint savings and adjusted energy savings
Hourly consumption data	PAs	• Account numbers • Service point IDs • 15- or 60-minute meter readings (consumption that occurred in the last 15 or 60 minutes)	Used to estimate unadjusted and adjusted peak demand savings

[8] Appendix E reports program attrition by wave and Appendix F presents a summary of data quality issues identified for these participants.

[9] DNV GL conducted a survey of HER customers for the evaluation in program year 2017, which were used to inform upstream joint savings. The survey was run in 2018/2019. Since there are not likely to be significant changes in such savings in one year, DNV GL used results from this survey for the 2018 evaluation. This balances the need for results that reflect recent activity and survey efforts that are not more frequent and burdensome to customers.

3.2 Unadjusted energy savings

DNV GL uses a fixed effects regression model for this evaluation, a standard for evaluating behavioral programs like HER. HER treatment and control groups are organized in a random controlled trial (RCT) experimental design framework that supports an un-biased estimate of the effect of a treatment applied to the treatment group. The RCT framework is the most effective way to establish a causal relationship between a treatment and its effect. The fixed effects model allows DNV GL to compare the treatment group's energy consumption to that of the control group before and after the HER program. The model tracks the effect of home energy reports on the treatment group's energy consumption.

Below is the fixed-effects regression model:

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

where:

E_{it}	=	Average daily energy consumption for customer i during month t
P_{it}	=	Binary variable: one for a customer in the treatment group in a post-program month t, zero otherwise
λ_t	=	Month-year fixed effect: one for a specific month/year, zero otherwise
μ_i	=	Customer fixed effect: one for a specific customer, zero otherwise
ε_{it}	=	Regression residual

Below is the equation for estimated average monthly savings:

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

where:

$\bar{S}_t$	=	Average reduction in energy consumption due to HERs during month t
$\hat{\beta}_t$	=	Estimated reduction in energy consumption due to HERs during month t

The model includes customer and month-year fixed effects. The customer fixed effects account for average differences between the treatment and control groups that do not change over time (i.e., square footage of house). The month-year fixed effects account for differences over time that affect both the treatment and control groups (i.e., changes in consumption between winter and summer months due to heating or cooling). In order to maintain the validity of the RCT, DNV GL does not remove HER recipients who opt to stop receiving reports as this impacts the treatment group but not the control group. Treatment for these customers is considered the "intent to treat". DNV GL removes customers (both treatment and control) who drop out of the HER program by moving (attrition) in the month they move as moveouts are assumed to affect both treatment and control equally.

Finally, total unadjusted annual energy savings for a HER wave equal the sum of average monthly savings, multiplied by the count of active report recipients in each respective month. This model remains 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".[10]

[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.

3.3 Unadjusted peak demand savings

Several approaches may be used to estimate peak demand reductions attributable to HER. In California the preferred approach examines differences in peak demand that occur between pre- and post-program peak periods. The Database for Energy Efficiency Resources (DEER) [11] offers a definition for the peak period which considers average temperature, average afternoon temperature (12 p.m. to 6 p.m.), and maximum temperature over three-day heatwave (HW) periods. Each candidate heatwave contains three consecutive, non-holiday weekdays between June 1 and September 30. DNV GL selects the optimal heatwave for each climate zone as the heatwave with the highest peak score ($Score_k$) among the candidates.

Below is the equation used to compute the optimal peak score among HW candidates:

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

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

where:

HW	=	Climate zone-specific set of three, consecutive, non-holiday weekdays that has the highest Score_k for heatwave candidate k among candidates K
Score_k	=	The sum of maximum, average daily, and afternoon average temperature
$daily\_max_{d,k}$	=	The maximum hourly temperature value on day d for HW candidate k
$daily\_mean_{d,k}$	=	The average hourly temperature on day d for HW candidate k
$afternoon\_avg_{d,k}$	=	The average hourly temperature from 12 p.m. to 6 p.m. on day d for HW candidate k

As the basis for the following regression model, DNV GL uses the 15- and 60-minute interval data from 2 p.m. to 5 p.m. during the optimal HW in each HER program year. The model produces estimates of peak demand savings due to the HERs:

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

where:

$\Delta\overline{kW}_i$	=	Average difference in demand for household $i$between the pre- and post-program periods during the DEER-defined peak period
T_i	=	Binary variable: one for a customer in the treatment group, zero otherwise
α, β	=	Model coefficients – β represents the average peak demand reduction due to HERs
ε_i	=	Model error term

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

3.4 Downstream rebate joint savings

Downstream joint savings are savings that occur because HER recipients purchase and/or install measures offered through downstream rebate programs at a higher rate than non-recipients. DNV GL estimates downstream joint savings using the RCT experimental design inherent in the HER program design. Downstream rebate activity compared between treatment and control groups provides an unbiased estimate of HER effect(s) on downstream program activity.

Even though the combination of both HER programs and downstream rebate programs led to these joint savings, it is essential that these savings are only claimed once. DNV GL uses the most practical approach: remove joint savings from HER unadjusted program savings instead of removing program-specific joint savings from each downstream rebate program. HER programs are evaluated after the end of the program year, so downstream programs in which HER recipients may participate, will have already claimed the jointly motivated program-specific savings. This approach is recommended in the State and Local Energy Efficiency Action Network (SEE Action) report. [12]

Specifically, DNV GL determines the daily share of annual savings for each tracked downstream rebate program measure using 2011 Database of Energy Efficiency Resources (DEER)[13] load shapes.[14] These load shapes indicate when customers would use each measure during the year and, by proxy, when energy savings would occur.[15] Savings for each measure accrue from the time of installation (or time of removal for refrigerator recycling), year over year, for the estimated useful life of the measure. That is, measures differentially installed in prior years may continue to contribute to joint savings up to and through 2018, which is the focus of this evaluation.

DNV GL then aggregates daily savings to average monthly savings for each customer, including customers who did not participate in a rebate program and therefore do not have downstream rebate program savings. After aggregating average monthly savings across customers in both the treatment and control group, DNV GL subtracts the control group's savings from the treatment group's savings. A positive difference represents the joint energy savings between HER and downstream rebate programs. DNV GL removes these joint savings from the unadjusted savings estimates.

DNV GL uses a similar approach to calculate downstream joint peak demand savings. This approach uses the kW savings for measures claimed by the downstream rebate program for HER customers (treatment and control) from the time of installation through each HER wave's designated peak period. Again, a positive difference in the average demand savings represents the joint demand savings between HER and downstream rebate programs.

[12] 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.

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

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

[15] This approach produces more accurate and equitable results than subtracting out the first-year savings values used in DEER because most measures are not in place from the first day to the last day of the year.

3.5 Upstream rebate joint savings

Upstream joint savings are savings that occurred because HER recipients were motivated to purchase and install CFL or LED light bulbs that were rebated through the Upstream Lighting Program at a greater rate than non-recipients. Unlike downstream rebate programs, there is no tracking database for treatment and control customer purchases of upstream rebated light bulbs. Hence, DNV GL uses a different method to estimate upstream joint savings and adjusts the overall savings estimates accordingly. Table 3-2. presents each input to the upstream lighting equation as well as the sources used for lightbulbs installed between 2011 and 2018. Appendix G contains inputs specific to program administrators. Below is the equation to calculate annual joint energy savings per recipient:

$$\begin{aligned} &Annual\ joint\ energy\ savings\ per\ customer \\ &\quad = Uplift\ due\ to\ HER * Rebated\ sales\ fraction \cdot Installed\ share\ of\ 2018 * Installation\ rate \\ &\quad * Net\ to\ gross\ ratio * Savings\ per\ lamp\ (kWh\ or\ therms) \end{aligned}$$

Table 3-2. Upstream lighting energy savings inputs

Variable	Description	Sources
Uplift due to HER	The positive difference between the count of bulbs installed by treatment and control group customers	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	The Upstream Lighting Program's fraction of bulbs purchased by each PA's customers	2014 and 2015 TRC HER lighting overlap studies
Installed share of 2018	The fraction of 2018 (in months) for which each PA's customers' bulbs were installed	Prior to 2018, 1; For 2018, .54
Installation rate	The fraction of purchased bulbs installed by each PA's customers	2013-14 Upstream Lighting Program Evaluation (DNV GL, 2016) prior to 2015, 1 after (already installed data)
Net-to-gross ratio	The share of savings claimable by either the HER programs or Upstream Lighting Program	2010-12 Upstream Lighting Program Evaluation (DNV GL, 2014), 2013-14 Upstream Lighting Program Evaluation (DNV GL, 2016), 2015 Upstream Lighting Program Evaluation (DNV GL, 2017), 2017 Upstream Lighting Program Evaluation (DNV GL, 2019)
Annual electric savings per bulb	The evaluated, quantity-weighted gross lighting savings per bulb each year	2010-12 Upstream Lighting Program Evaluation (DNV GL, 2014), 2014 TRC HER lighting overlap study, Program tracking data (DEER 2013-14), 2015 Upstream Lighting Program Evaluation (DNV GL, 2017), 2017 Upstream Lighting Program Evaluation (DNV GL, 2019)

Variable	Description	Sources
Annual gas interactive effects per bulb	The evaluated, quantity-weighted gross interactive effects per bulb each year	2013-14 Upstream Lighting Program Evaluation (DNV GL, 2016), 2015 Upstream Lighting Program Evaluation (DNV GL, 2017), 2017 Upstream Lighting Program Evaluation (DNV GL, 2019)

In the absence of a tracking database for upstream rebated measures, DNV GL conducted a survey in 2017 to estimate CFL and LED light bulb *uplift* (purchased and installed) by HER customers (treatment and control). DNV GL uses the data from the 2017 survey to estimate uplift in 2018, as well.

The *rebated sales fraction* from the table above accounts for the Upstream Lighting Program's contribution to all bulbs purchased by each PA's customers. Since HER might motivate the purchase of bulbs not rebated as part of the Upstream Lighting Program, DNV GL applies this adjustment to the survey-measured uplift.

Next, the *installed share of 2018* accounts for the fraction of the current evaluation year (in months) for which a bulb was installed. Since some purchased bulbs were not installed for each month of 2018, assuming flat installation of bulbs throughout the year,[16] DNV GL applies this adjustment to the survey-measured uplift as well.

The *installation rate* accounts for the fraction of purchased bulbs that were installed by each PA's customers. Since some customers purchase bulbs that they do not immediately install, DNV GL applies this adjustment factor to the survey-measured uplift for bulbs purchased from 2011 to 2014. When DNV GL first launched an online survey in 2015, it collected data on installed bulbs directly, so DNV GL does not apply this factor to uplift measured after 2014.

The *net-to-gross (NTG) ratio* accounts for the share of savings attributable entirely to the HER or Upstream Lighting programs.[17] The NTG factor represents the ratio of net lighting savings to gross lighting savings. DNV GL estimated this value in the latest Upstream Lighting Program evaluation. The NTG ratio represents the combined NTG factor across bulb types, weighted by the number of bulbs rebated through the Upstream Lighting Program. Since the upstream joint savings estimates would otherwise include savings by customers who would have installed bulbs in the absence of the HER or Upstream Lighting program(s), DNV GL applies this ratio to the survey-measured uplift.

The *annual electric savings per bulb (kWh)* represent the gross lighting savings each year, weighted by the number of bulbs rebated through the Upstream Lighting Program. DNV GL estimated this value in the latest Upstream Lighting Program evaluation. To convert uplift (in number of bulbs) to upstream electricity savings (kWh), DNV GL applies this factor to the survey-measured uplift to calculate the annual joint electric savings per recipient.

The *annual gas interactive effects per bulb (therms)* represent the gross interactive effects from uplift each year, weighted by the number of bulbs rebated through the Upstream Lighting Program. DNV GL estimated this value in the latest Upstream Lighting Program evaluation. When a customer replaces inefficient bulbs with efficient bulbs, they may increase their gas-fueled heating loads due to the reduced heat emissions from the

[16] 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 value of these fractions is 0.54, the value used for the installed fraction of 2018.

[17] In almost any energy efficiency program, some percentage of program participants would have bought the rebated measure in the absence of the program. These participants are referred to as free-riders and their savings are not considered to be program attributable.

bulbs themselves. Accordingly, DNV GL applies this factor to the survey-measured uplift to calculate the annual gas interactive effects per bulb.

Below is the equation to calculate total upstream joint energy savings:

$$Total\ upstream\ joint\ energy\ savings = \sum_{m=1}^{12} \left(\begin{matrix} Treatment\ customer_m * \\ (CFL\ joint\ energy\ savings_{m,y} + LED\ joint\ energy\ savings_{m,y}) \end{matrix} \right)$$

Specifically, DNV GL divides annual joint energy savings per recipient by 12 to calculate the monthly share of upstream joint savings. DNV GL then sums the monthly savings across bulb types (CFLs and LEDs) and years to calculate aggregated monthly savings. Next, DNV GL multiplies this value by the number of active HER treatment group customers as of the respective month in 2018. Finally, DNV GL sums these values across months. The total upstream joint energy savings is therefore adjusted for changes in bulb installation over time. If total upstream joint energy savings amounts to a negative value for any wave, then DNV GL attributes zero joint energy savings between that HER wave and the Upstream Lighting program.

Table 3-3 presents inputs specific to the upstream peak demand savings calculation as well as the sources used for bulbs installed between 2011 and 2018. Appendix G contains inputs specific to program administrators.

Below is the equation to calculate annual joint demand savings per recipient:

$$\begin{aligned} &Annual\ joint\ peak\ demand\ savings\ per\ customer \\ &= Uplift\ due\ to\ HER \cdot Rebated\ sales\ fraction * nstalled\ share\ at\ peak * Installation\ rate \\ &* Net\ to\ gross\ ratio * \frac{Delta\ watts}{1000} * Peak\ coincidence\ factor \end{aligned}$$

Table 3-3. Upstream lighting peak demand reduction inputs

Variable	Description	Sources
Installed share at peak	The fraction of 2018 (in days) for which bulbs were installed, due to the HER program	Calculated as the percent of days from January 1 until each year's heatwave occurs
Delta watts	The difference in wattage between a baseline inefficient (CFL) bulb and the more efficient bulb	2017 Upstream Lighting Program Evaluation (DNV GL, 2019)
Peak coincidence factor	Transforms savings in kWh to peak period kW effect.	2017 Upstream Lighting Program Evaluation (DNV GL, 2019)

The *installed share at peak* accounts for the fraction of the current evaluation year (in days) for which a bulb was installed. Since some bulbs were not installed before the designated peak period, assuming even installation of bulbs throughout the year, DNV GL applies this adjustment to the survey-measured uplift.

The *delta watts* account for the savings that occur when switching out an inefficient bulb with a more efficient bulb. DNV GL applies the delta watts factor to the survey-measured uplift to adjust for this technological trend.

The *peak coincidence factor* transforms kWh savings to peak kW reduction.

Below is the equation to calculate total upstream joint peak demand savings:

$$Total\ upstream\ joint\ peak\ demand\ savings = \sum_{m=1}^{12} \left(\begin{array}{c} Treatment\ customer_m * \\ (CFL\ joint\ peak\ demand\ savings_{m,y} + LED\ joint\ peak\ demand\ savings_{m,y}) \end{array} \right)$$

Specifically, DNV GL multiplies the delta watts value by the peak coincidence factor to convert annual electricity savings per bulb to demand savings per bulb. Then, DNV GL sums those demand savings across bulb types (CFLs and LEDs) and years to calculate aggregated peak load reduction. Next, DNV GL multiplies this value by the number of active HER treatment group recipients as of the respective peak period in 2018 to calculate the total upstream joint peak demand savings. If total upstream joint peak demand savings amount to a negative value for any wave, then DNV GL attributes zero joint peak demand savings between that HER wave and the Upstream Lighting program.

3.6 Load savings shapes

The methods discussed in the prior sections examine how DNV GL estimates energy savings (kWh and therms) and peak demand reduction (kW) attributable to the HER program. These savings provide answers to 'what' the program achieves. In order to understand 'when' these savings occur, DNV GL examined the savings or impact load shape from the program. Load savings shapes identify the 8760 hourly[18] load savings and, thus, the periods during which program savings occur. The hourly load savings shapes from the analysis also provides information on how HER recipients' energy consumption habits may change over time and how these changes relate to the HER program.

DNV GL used customer or site-level regressions and difference-in-difference models to estimate load savings shapes for the program. The site-level regressions were used to produce separate annual hourly load shapes for treatment and control group customers. The estimated hourly load shapes were then used in difference-in-difference models to generate hourly load shapes savings that identify when savings from the program occur.

The site-level hourly regression models are based on pre- and post-program data. Pre-program data informs baseline conditions. The regression models based on hourly loads during these periods take the following form:

$$Y_{ih} = \alpha_h + \beta_h^H H_o + \beta_h^C C_o + \varepsilon_h$$

Y_h = consumption for a given customer i and hour h

H_o, C_o = heating and cooling degree days from a specified or optimized base

α_h = baseload for hour *h*

β_h^C, β_h^H = Cooling and heating trends for hour *h* as a function of degree days

The cooling degree days (CDD) and heating degree days (HDD) used in the site-level model are metrics used to measure the relative amount of energy needed to cool or heat buildings based on the temperature at which a household begins to use their heating or cooling system (called a reference temperature). The daily models use 365-day data for each site to identify heating and cooling slopes, if present, and the optimal reference heating and cooling temperature for each site. The optimal daily model heating and cooling reference temperatures were used in the hourly load shape models.

Using the identified optimized base and model results for each site, hourly consumption estimates for the pre- and post-program periods can be generated based on the following formula:

$$\hat{Y}_{ih} = \hat{\alpha}_h + \hat{\beta}_h^H \ddot{H}_o + \hat{\beta}_h^C \ddot{C}_o$$

$\hat{Y}_{ih}$ = estimated consumption for a given customer i for hour h

$\ddot{H}_o$, $\ddot{C}_o$ = TMY/CZ2018 heating and cooling degree days from reference temperature used in regression.

DNV GL applied this model to a full year of hourly data in both the pre- and post-program periods, meaning the year prior to recipients first receiving reports and 2018. The models used data from both treatment and control groups and provide predictions of consumption for all hours of the year based on TMY/CZ2018

[18] 8760 are the total number of hours in a year.

weather for a chosen actual weather year. CZ2018 are typical meteorological year weather data for select California weather stations that are useful for long-term weather normalization.

Predicted consumptions for all hours from the pre- and post-period were used in a difference-in-difference regression to produce hourly load savings shape. DNV GL fit the difference-in-difference model using the methodology as published in Chapter 17, section 4.4.5 of the Uniform Methods Project.[19] Estimated hourly load savings shape is given by:

$$\Delta Y_h = \left(\hat{Y}_h^{part,pre} - \hat{Y}_h^{part,post}\right) - \left(\hat{Y}_h^{np,pre} - \hat{Y}_h^{np,post}\right)$$

ΔY_h = treatment effect for hour *h*

$Y_h^{part,pre}$ = the average load across participants in the pre-period for hour *h*

$Y_h^{part,post}$ = the average load across participants in the post-period for hour *h*

$Y_h^{part,pre}$ = the average load across non-participants in the pre-period for hour *h*

$Y_h^{part,pre}$ = the average load across non-participants in the post-period for hour *h*

DNV GL applied this approach to estimate hourly load and savings shapes for select HER waves. DNV GL chose Wave 4 from PG&E, Opower 4 from SCE and Opower 3 from SDG&E based on tenure and their representative customer segment among HER recipients: dual fuel and high energy users[20]. Since this is the first undertaking of its type for the HER evaluation and the data requirements were substantial, DNV GL conducted the study using data from a random subset of households from these waves as a proof of concept. All three chosen waves began in the mid 2010's and involved over 200,000 recipients. In 2019, each of these waves still had substantial number of recipients post attrition and DNV GL used data from 10,000 randomly chosen homes from both the treatment and control groups for each utility.

3.7 Savings persistence

HER program reports are delivered to households randomly selected to receive them at program launch. By program design, report delivery to the home stops when a customer at the participating treatment household moves,[21] which is most commonly indicated by customer identifier changes in utility billing records. It is useful to examine if HER induced savings persist for new residents in homes previously occupied by report recipients, since it has implications about the program's savings and cost effectiveness. It can also shed light on the mechanism through which the HER program encourages savings.

A recent study by Brandon et al. (2017) sets out to answer the latter question and provides a framework we adopt to study the persistence of HER savings post attrition.[22] The study examines whether habit formation or the energy efficiency changes made to the home drive HER savings. The study authors theorize that current outcomes depend on historic physical factors put in place the effect(s) of which persist rather than through habit formation. This theory is informed by evidence of short-lived effects of programs that offer incentives to induce behavior changes. Such programs, which abound outside of the energy field, have often failed to produce lasting effects.

[19] NREL. https://www.energy.gov/eere/about-us/ump-protocols

[20] SCG does not provide electricity.

[21] Report delivery may also stop when a recipient requests to stop receiving reports; however, they are not removed from the program for evaluation purposes to preserve the integrity of the RCT as opting out impacts the treatment group but not the control group.

[22] Brandon, A., J. Ferraro, J.A. List, R. D. Metcalf, M. K. Price, F. Rundhammer, Do the Effects of Social Nudges Persist? Theory and Evidence from 38 Natural Field Experiments, Working Paper 23277 http://www.nber.org/papers/w23277

However, HER is the one well-documented case where there have been enduring effects from program-induced changes. The program does not offer incentives but uses social nudges that have produced measurable energy savings that have persisted over time. Researchers have attributed these enduring savings to habit formation after examining and finding little to no evidence of uplift in other utility offered energy efficiency programs among HER treatment households.[23]

Brandon et al. indicate HER treatment households could still be adopting more energy efficient measures and appliances outside of utility programs and, thus, what drives HER program savings is still an open question. They use data from both current and sites previously occupied by HER treatment households to address this question. Savings among the latter points to the role of the presence of more efficient home improvements being responsible for HER savings.

DNV GL uses the research framework proposed by these authors to examine the effect of attrition on HER savings. The California IOU HER programs provide a rich background for this research. Like the load savings shape research, DNV GL chose a HER wave for this exploratory analysis based on tenure and the customer segment represented. Data from PG&E's HER Wave 3 fits the bill as it involves high usage dual fuel customers and has a sufficiently long history with long time-series data both from treatment customers that are still receiving reports as well as those that have left their homes. The change in home ownership allows for the identification of the effect of capital investment due to HER and its effect on HER savings persistence.

The model used to estimate the effect of the HER program on homes after a recipient has moved is a modification to the panel fixed effects difference-in-difference method traditionally used to estimate the effect of the HER program. It is given by:

$$E_{it} = \mu_i + \lambda_t + \beta_t P_{it} + \beta_m M_t + \beta_{mt} M_t P_{it} + \varepsilon_{it}$$

where:

E_{it} = Average daily energy consumption for customer i during month t
P_{it} = Binary variable: one for a customer in the treatment group in a post-program month t, zero otherwise
M_t = Binary variable: one for a customer in the either the treatment or control group that moves in a post-program month t, zero otherwise
$M_t P_{it}$ = Binary variable: one for a customer in the treatment group that moves in a post-program month t, zero otherwise
λ_t = Month-year fixed effect: one for a specific month/year, zero otherwise
μ_i = Customer fixed effect: one for a specific customer, zero otherwise
β_t = Average reduction in energy consumption due to HERs during month t for active treatment customers
β_{mt} = Average reduction in energy consumption due to HERs during month t for movers
ε_{it} = Regression residual

The coefficient estimate $\hat{\beta}_{mt}$ is the estimated average monthly savings for movers that captures HER treatment effects after homes change ownership. The natural experiment created by movers helps identify the role energy efficient capital investments play in HER savings, in general, and measures the persistence of savings in homes previously occupied by HER treatment customers.

[23] Allcott, Hunt, and Todd Rogers. 2014. "The Short-Run and Long-Run Effects of Behavioral Interventions: Experimental Evidence from Energy Conservation," American Economic Review, 104(10): 3003-037.

4 PG&E IMPACT RESULTS

4.1 Unadjusted electric and gas savings estimates

Pacific Gas & Electric (PG&E) administers 15 HER waves. Table 4-1 summarizes important features of each wave, including the launch date, report frequency, fuel type, energy use quartile and geographic area. These features vary across waves and lead to variation in HER-related savings across waves.

Table 4-1. PG&E HER waves, program year 2018

Wave	Launch Date	Report Frequency	Fuel	Usage Quartile	Region	Initial Treatment Customers	Initial Control Customers
Beta	Jul-2011	Monthly	Dual	Highest	San Francisco Bay area	59,994	59,994
Gamma standard	Nov-2011	Monthly	Dual	All	6 PG&E baseline territories	72,287	72,292
Gamma reduced	Nov-2011	Quarterly	Dual	All	6 PG&E baseline territories	72,286	
Gamma electric-	Nov-2011	Monthly	Electric-only	All	6 PG&E baseline territories	44,985	44,992
Wave 1 dual fuel	Feb-2012	Monthly	Dual	Top three	All	360,200	89,993
Wave 1 electric-	Feb-2012	Monthly	Electric-only	Top three	All	39,787	9,999
Wave 2 area 7	Feb-2013	Monthly	Dual	Top three	Humboldt, Mendocino, Lake, and Sonoma counties	80,051	50,071
Wave 2 non-area 7	Feb-2013	Monthly	Dual	Top three	All other counties	305,284	47,708
Wave 3	Jul-2013	Monthly	Dual	Top three	All	224,996	75,020
Wave 4	Mar-2014	Monthly	Dual	Top three	All	200,000	75,000
Wave 5	Oct-2014	Monthly	Dual	Top three	All	210,000	50,200
Wave 6	Sep-2015	Monthly	Dual	Top three	All	312,000	50,000
Wave 7	Mar-2017	Monthly	Dual	Top three	All	157,496	39,997
Wave 8	Nov-2017	Monthly	Dual	All	All	142,994	22,000
Wave 9	Aug-2018	Monthly	Dual	Top three	All	104,859	19,976

Figure 4-1 and Figure 4-2 present the annual unadjusted electric and gas savings per recipient. The highest electric and gas savings come from recipients in the Beta wave. The Beta wave was the first HER report wave implemented by PG&E and included only the highest quartile energy users in the San Francisco Bay area. Most other waves included broader customer groups. Waves 7, 8 and 9 started in 2017 or 2018, and savings levels are unlikely to reflect the higher savings levels they will reach in their third or fourth year. Other wave characteristics listed in Table 4-1 explain the remaining variability in savings estimates.

Figure 4-1. PG&E annual unadjusted electric savings per recipient, program year 2018

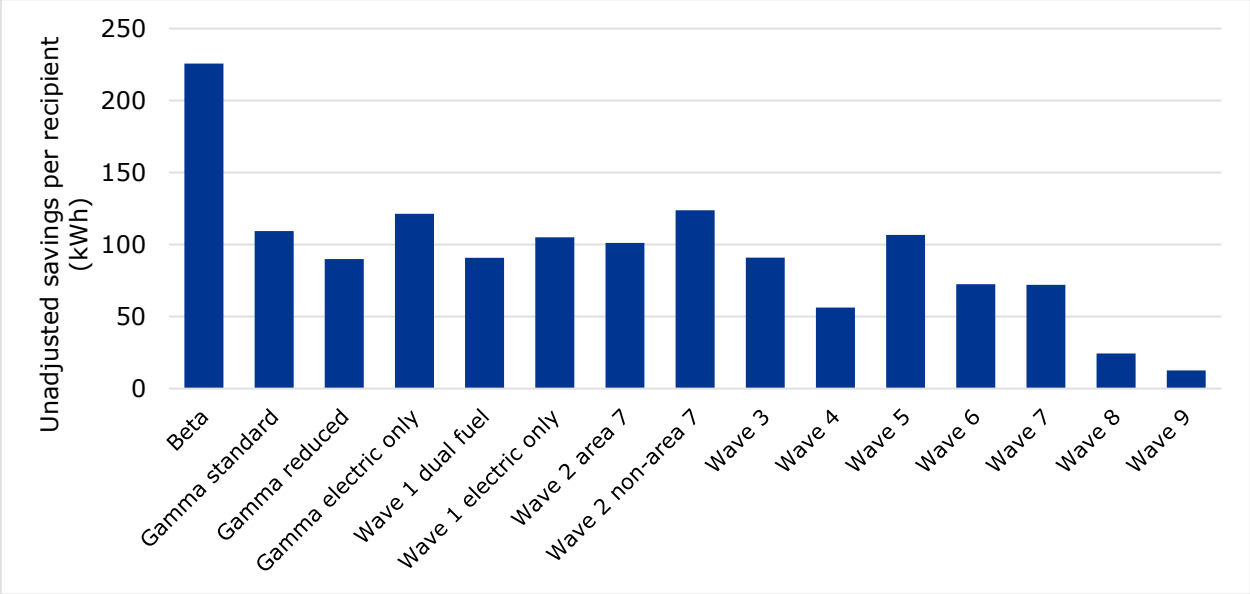


Figure 4-2. PG&E annual unadjusted gas savings per recipient, program year 2018

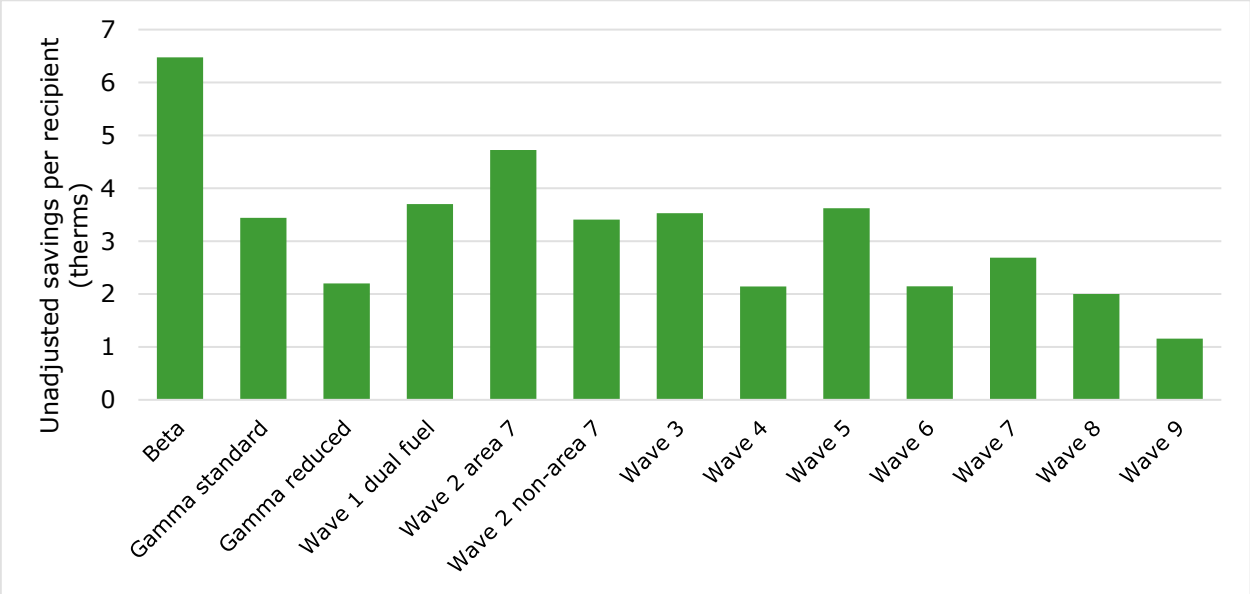


Table 4-2. provides percent savings, baseline electricity use, the number of customers in the treatment group, and savings magnitude in kWh at both per customer and wave levels. PG&E's HER customers produced 134

GWh of unadjusted electric savings in 2018. Depending on the wave, report recipients saved between 0.4% and 2.6% of baseline electricity consumption.

Table 4-2. PG&E total unadjusted electric savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Electric (kWh)							
Beta	8,801	37,978	226	8,570,816	6,539,305	10,602,327	2.6%
Gamma standard	6,221	43,265	109	4,732,630	2,933,444	6,531,817	1.8%
Gamma reduced	6,221	43,293	90	3,895,389	2,124,622	5,666,156	1.4%
Gamma electric only	6,431	20,510	121	2,489,259	1,327,172	3,651,345	1.9%
Wave 1 dual fuel	6,203	225,414	91	20,466,413	14,773,836	26,158,990	1.5%
Wave 1 electric only	7,031	20,361	105	2,139,807	8,979	4,270,635	1.5%
Wave 2 area 7	5,521	52,959	101	5,358,361	3,603,799	7,112,923	1.8%
Wave 2 non-area 7	5,992	206,486	124	25,571,399	19,486,406	31,656,392	2.1%
Wave 3	6,011	136,467	91	12,408,733	8,460,733	16,356,733	1.5%
Wave 4	5,545	113,644	56	6,397,623	3,166,518	9,628,728	1.0%
Wave 5	8,111	135,060	107	14,408,621	9,061,014	19,756,229	1.3%
Wave 6	5,809	195,361	72	14,156,111	8,880,839	19,431,383	1.2%
Wave 7	6,314	125,310	72	9,035,212	5,791,382	12,279,043	1.1%
Wave 8	2,604	129,907	24	3,127,076	1,862,410	4,391,742	0.9%
Wave 9	3,435	98,054	13	1,238,920	-2,688	2,480,529	0.4%

Note: The average number of treatment participants indicates wave size. Total unadjusted electric savings are based on counts of active customers in the treatment group.

Table 4-3. provides percent savings, baseline gas use, the number of customers in the treatment group, and savings magnitude in therms at both per recipient and wave levels. PG&E's HER recipients produced 4.6 million therms of unadjusted gas savings in 2018. Depending on the wave, report recipients saved between 0.5% and 1% of baseline gas consumption.

Table 4-3. PG&E total unadjusted gas savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Gas (therms)							
Beta	702	38,132	6	246,935	133,820	360,050	0.9%
Gamma standard	405	43,297	3	149,019	69,086	228,953	0.8%
Gamma reduced	405	43,502	2	95,797	17,346	174,247	0.5%
Wave 1 dual fuel	419	225,377	4	834,447	564,186	1,104,709	0.9%
Wave 2 area 7	469	53,072	5	250,669	154,344	346,994	1.0%
Wave 2 non-area 7	426	207,018	3	705,387	396,887	1,013,887	0.8%
Wave 3	428	137,270	4	484,583	297,489	671,676	0.8%
Wave 4	393	113,957	2	244,368	95,699	393,037	0.5%
Wave 5	489	135,874	4	492,285	259,433	725,138	0.7%
Wave 6	398	196,801	2	422,153	169,887	674,418	0.5%
Wave 7	411	126,683	3	340,518	191,799	489,238	0.7%
Wave 8	251	129,803	2	212,578	98,595	326,561	0.7%
Wave 9	177	97,493	1	112,961	30,562	195,359	0.7%

Note: The average number of treatment participants indicates wave size. Total unadjusted savings are based on counts of active customers in the treatment group.

Figure 4-3 and Figure 4-4 present historical estimates of annual unadjusted electric and gas savings per report recipient as a percentage of baseline use. The figures show that recipients in most waves appear to gradually increase electric savings during the first years of receiving HER. After several years, the savings trends appear to plateau, after which there is year-to-year variability that reflects weather and other random differences.

Figure 4-3. PG&E annual unadjusted percentage electric savings per recipient, program year 2018

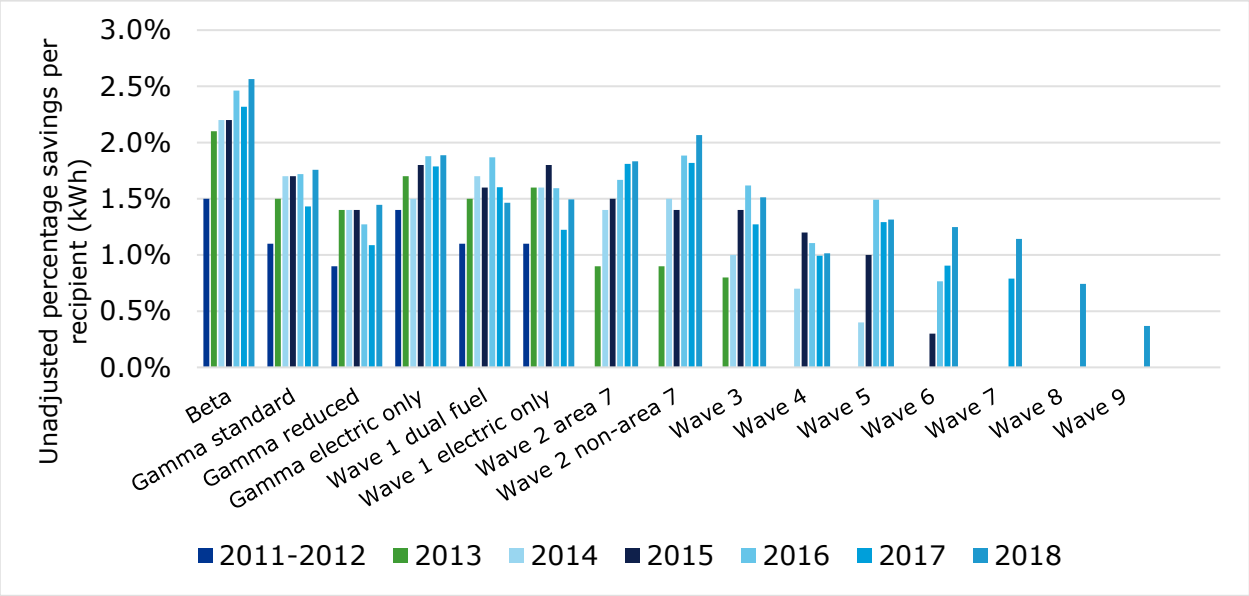
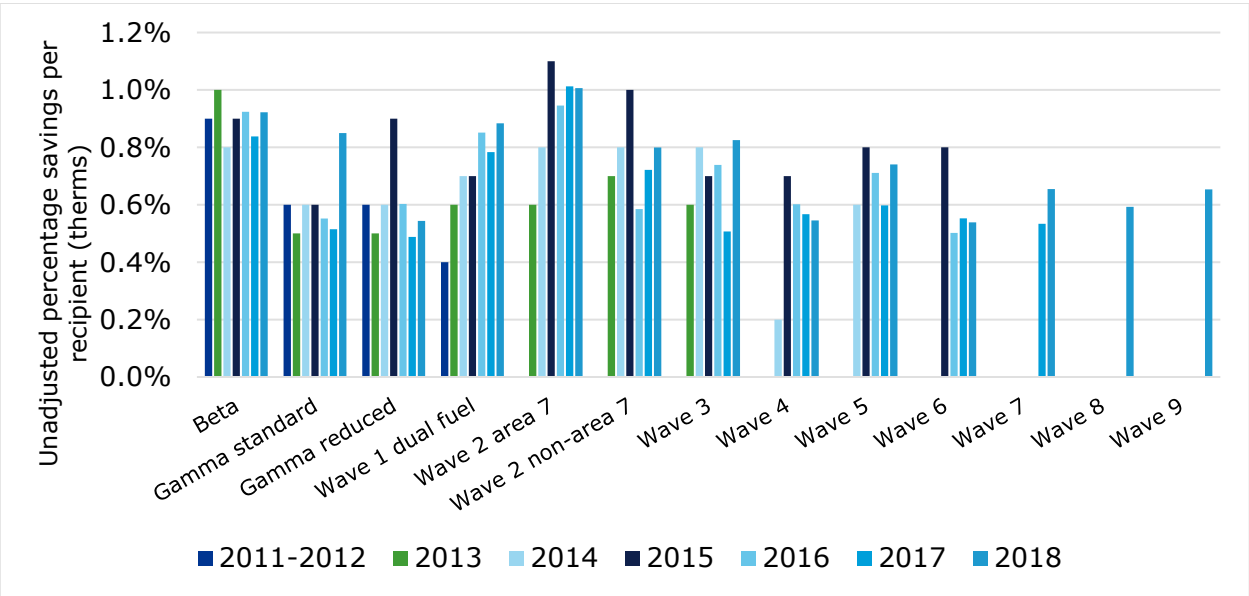


Figure 4-4. PG&E annual unadjusted percentage gas savings per recipient, program year 2018



4.2 Unadjusted demand savings estimates

4.2.1 Heat waves

Table 4-4. presents the optimal heatwave (HW) for each PG&E HER program year, as well as the optimal HW in the 2018 evaluation year. As noted previously, the optimal heatwave has the highest score of consecutive, three-day, weekday candidate periods. The score is based on average temperature, average afternoon temperature (12 p.m. to 6 p.m.), and maximum temperature over the HW. Because PG&E did not launch Wave 9 until after the optimal heatwave in 2018, recipients in Wave 9 do not contribute to estimates of unadjusted peak demand savings for the current evaluation year.

Table 4-4. PG&E DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2018 Post-Period
Beta	7/4/2011	-	7/6/2011	7/9/2018 – 7/11/2018
Gamma standard	7/4/2011	-	7/6/2011	
Gamma reduced	7/4/2011	-	7/6/2011	
Gamma electric only	7/4/2011	-	7/6/2011	
Wave 1 dual fuel	7/4/2011	-	7/6/2011	
Wave 1 electric only	7/4/2011	-	7/6/2011	
Wave 2 area 7	7/10/2012	-	7/12/2012	
Wave 2 non-area 7	7/10/2012	-	7/12/2012	
Wave 3	7/10/2012	-	7/12/2012	
Wave 4	7/2/2013	-	7/4/2013	
Wave 5	7/30/2014	-	8/1/2014	
Wave 6	7/30/2014	-	8/1/2014	
Wave 7	7/26/2016	-	7/28/2016	
Wave 8	8/30/2017	-	9/1/2017	

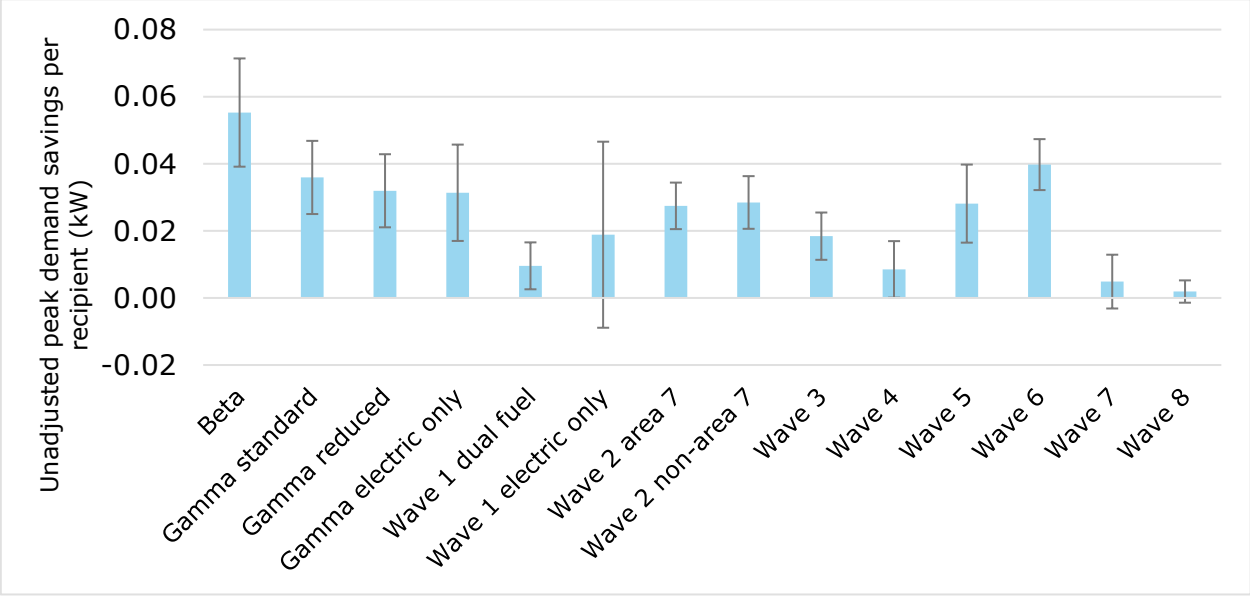
4.2.2 Peak demand savings

As shown in Table 4-5., PG&E's HER recipients produced 31 MW of unadjusted peak demand savings in 2018. Figure 4-5 presents estimates of annual unadjusted peak demand savings per recipient. Recipients in the Beta wave achieved the greatest peak demand savings.

Table 4-5. PG&E total unadjusted peak demand savings, program year 2018

Wave	Active Accounts during Peak Period (Jul. 9 - Jul. 11, 2018)	Total Peak Demand Savings (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Beta	37,881	2,093.6	1,088.1	3,099.0
Gamma standard	43,146	1,550.1	775.9	2,324.3
Gamma reduced	43,199	1,380.4	606.2	2,154.6
Gamma electric only	20,436	640.8	158.0	1,123.6
Wave 1 dual fuel	225,179	2,155.8	-433.9	4,745.4
Wave 1 electric only	20,259	381.9	-542.3	1,306.0
Wave 2 area 7	52,796	1,449.4	847.0	2,051.7
Wave 2 non-area 7	206,075	5,865.4	3,203.6	8,527.1
Wave 3	136,218	2,508.7	928.5	4,088.9
Wave 4	113,413	965.3	-606.5	2,537.1
Wave 5	134,509	3,782.9	1,207.0	6,358.8
Wave 6	195,230	7,760.1	5,320.8	10,199.4
Wave 7	125,141	609.7	-1,041.0	2,260.4
Wave 8	129,928	248.0	-463.4	959.3
Total	**1,483,410**	**31,392**	**11,048**	**51,735**

Figure 4-5. PG&E unadjusted annual peak demand savings per recipient, program year 2018



4.3 Downstream rebate joint savings

As Table 4-6. shows, PG&E's HER recipients' participation in downstream rebate programs produced 905 MWh, 737 therms, and 0.75 MW of downstream joint savings in 2018.

Table 4-6. PG&E total downstream joint savings by wave, program year 2018

Wave	Electric (kWh)	Gas (therms)	Peak Demand (kW)
Beta	77,527	0	53.5
Gamma standard	13,714	543	28.2
Gamma reduced	0	0	0.0
Gamma electric only	52,118	NA	87.7
Wave 1 dual fuel	259,697	0	122.6
Wave 1 electric only	17,855	NA	8.1
Wave 2 area 7	26,475	0	14.7
Wave 2 non-area 7	100,234	0	20.9
Wave 3	224,196	0	129.3
Wave 4	5,840	0	80.1
Wave 5	120,264	0	98.5
Wave 6	7,047	0	102.2
Wave 7	0	141	0.0
Wave 8	0	47	0.7
Wave 9	0	6	0.0
Total	**904,968**	**737**	**746.5**

Figure 4-6 and Figure 4-7 present estimates of downstream annual joint electric and gas savings per recipient. Some electric waves produced statistically significant downstream joint savings most estimates of downstream joint gas savings remain statistically indistinguishable from zero or are negative.

Figure 4-6. PG&E downstream annual joint electric savings per recipient, program year 2018

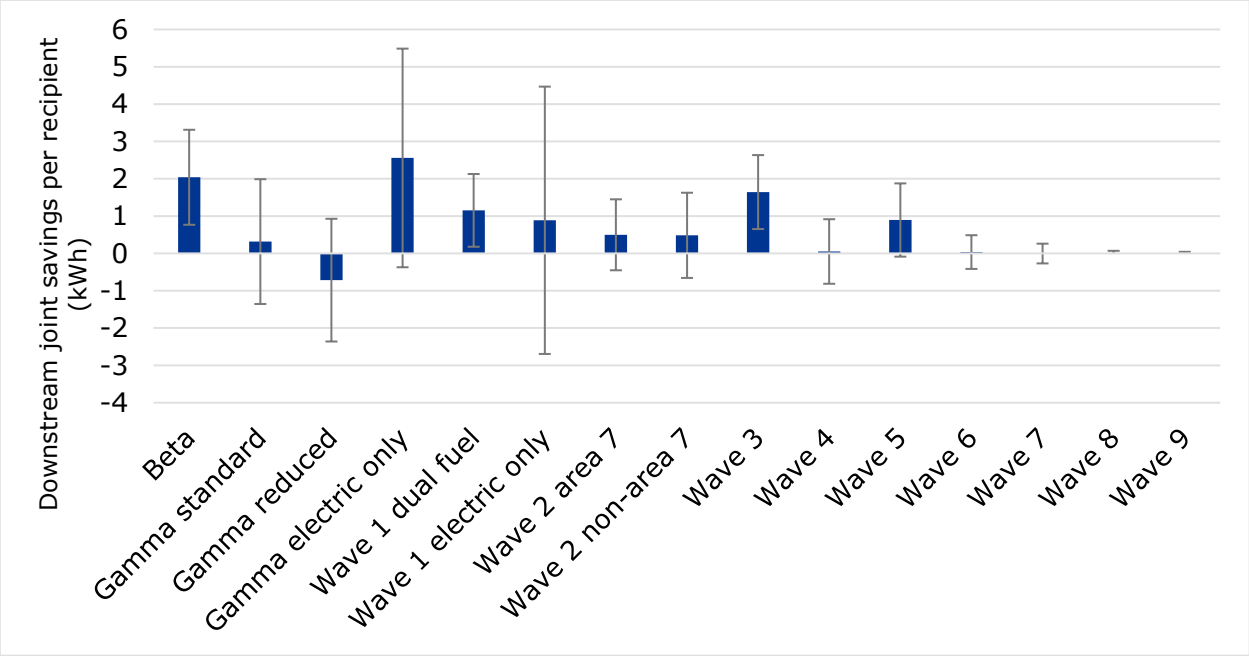


Figure 4-7. PG&E downstream annual joint gas savings per recipient, program year 2018

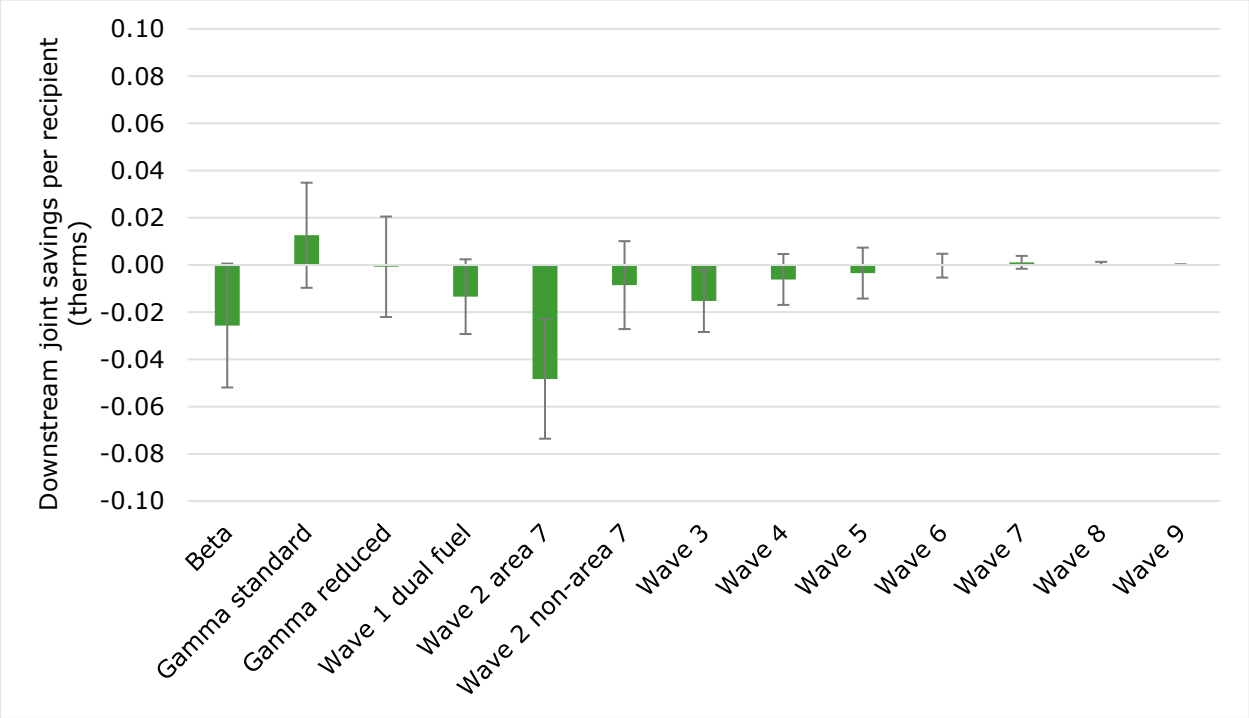
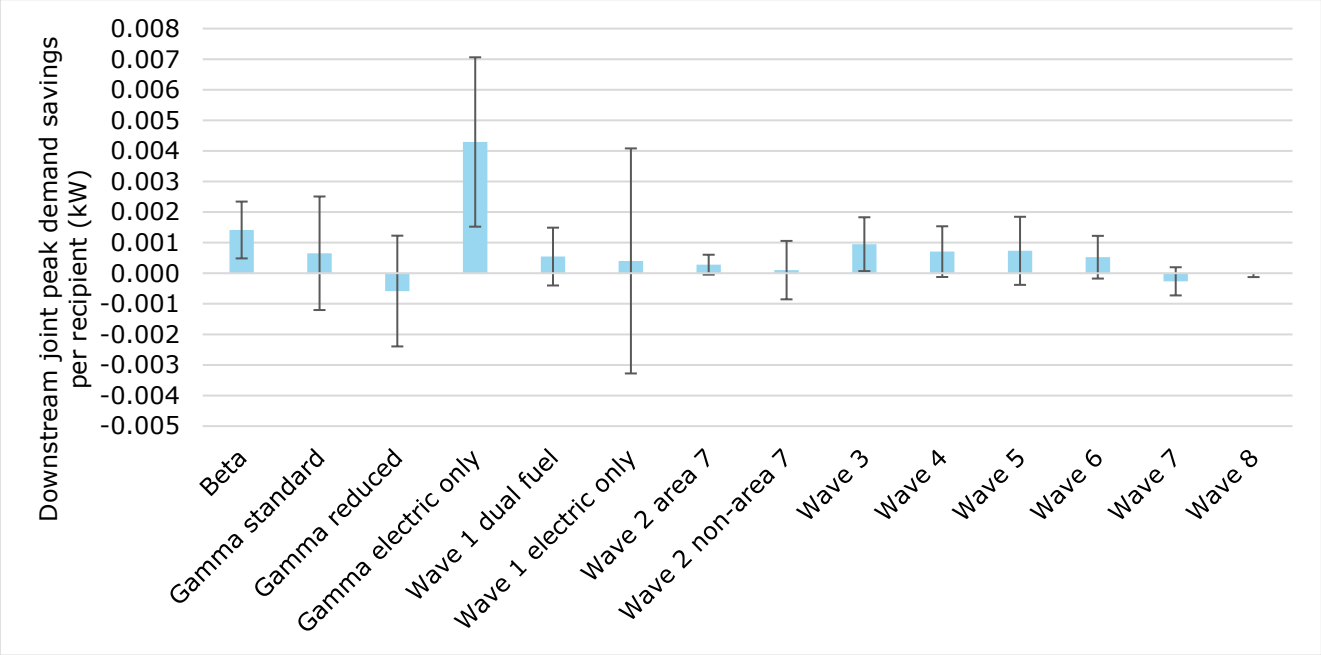


Figure 4-8 presents estimates of downstream annual joint peak demand savings per recipient. Most estimates of downstream joint peak demand savings remain statistically indistinguishable from zero gas savings.

Figure 4-8. PG&E downstream annual joint peak demand savings per recipient, program year 2018



4.4 Upstream rebate joint savings

Table 4-7. presents estimates of upstream annual joint savings per recipient. PG&E's HER recipients produced 7,476 MWh and 0.64 MW of upstream joint savings in 2018 (Table 4-8). Appendix G presents the PA-specific inputs to the upstream calculations. Note, most terms in the calculations have strictly positive values, while the uplift (purchase and installation of bulbs) would have a negative value in years when control group customers purchased or installed more CFLs or LEDs than treatment group customers; or, in most cases the interactive gas effect would have a negative value as heating load increases after installing bulbs with less heat emissions bulbs.

The contribution to upstream joint savings from CFLs and LEDs varies across waves. Most estimates of annual upstream joint electric savings are positive. These results support the idea that HER exerts a range of effects on joint electric savings with the Upstream Lighting program, depending on wave features as well as the type of bulb. Also, the analysis produced near-zero estimates for upstream joint peak demand savings.

Table 4-7. PG&E upstream annual joint savings per recipient, program year 2018

Wave	Upstream Joint Savings per Recipient per Year				
	Electric (kWh)			Interactive Effects (therms)	Peak Demand (kW)
	CFL	LED	Total		
Beta	9	2	11	>-1	<0.1
Gamma standard	10	<1	7	>-1	<0.1
Gamma reduced	8	>-1	8	>-1	<0.1
Gamma electric only	7	12	19	NA	<0.1
Wave 1 dual fuel	7	10	17	>-1	<0.1
Wave 1 electric only	7	9	16	NA	<0.1
Wave 2 area 7	2	<1	0	0	0
Wave 2 non-area 7	>-1	7	6	>-1	<0.1
Wave 3	<1	2	3	>-1	<0.1
Wave 4	<1	<1	0	0	0
Wave 5	1	<1	0	0	<0.1
Wave 6	<1	<1	1	>-1	<0.1
Wave 7	>-1	<1	0	0	0
Wave 8	>-1	<1	0	0	0
Wave 9	0	<1	0	0	0
Total	**51**	**24.9**	**89**	**-2**	**<0.1**

Table 4-8. PG&E total upstream joint savings by wave, program year 2018

Wave	Total Upstream Joint Savings		
	Electric (kWh)	Interactive Effects (therms)	Peak Demand (kW)
Beta	435,230	-12,325	40.7
Gamma standard	307,568	-9,358	39.1
Gamma reduced	344,151	-10,336	37.6
Gamma electric only	397,590	NA	30.3
Wave 1 dual fuel	3,775,179	-98,187	313.8
Wave 1 electric only	326,278	NA	27.5
Wave 2 area 7	0	0	0
Wave 2 non-area 7	1,323,814	-34,271	70.9
Wave 3	363,916	-9,742	32.1
Wave 4	0	0	0
Wave 5	0	0	11.6
Wave 6	202,244	-4,368	32.8
Wave 7	0	0	0
Wave 8	0	0	0
Wave 9	0	0	0
Total	**7,475,971**	**-178,587**	**636.6**

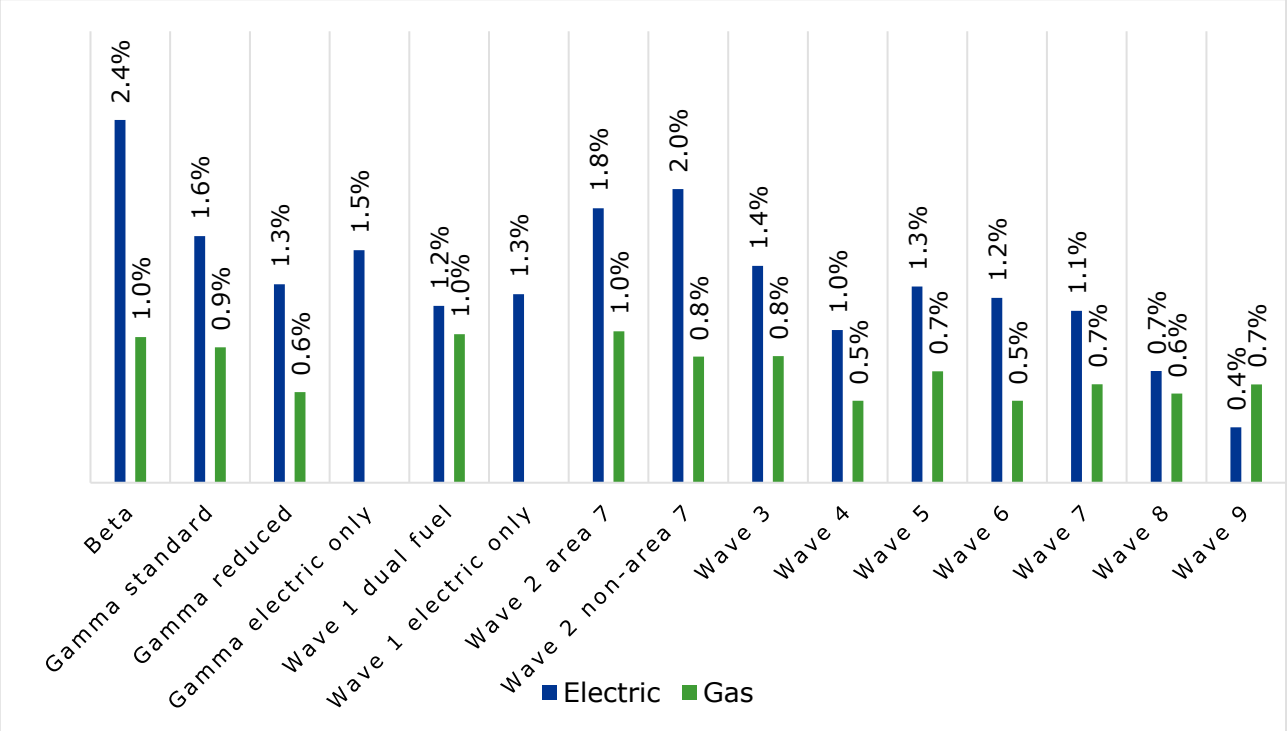
4.5 Total (adjusted) program savings estimates

Table 4-9. presents the total (adjusted) savings for PG&E's HER program in 2018, while Appendix D presents figures that show the relative magnitude of the downstream and upstream joint savings adjustments. Figure 4-9 compares adjusted HER program electric and gas savings as a percentage of baseline energy use.

Table 4-9. PG&E total savings for the 2018 HER program

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	133,996,371
Joint Downstream	904,968
Joint Upstream	7,475,971
Adjusted	125,615,431
Gas (therms)	
Unadjusted	4,591,699
Joint Downstream	737
Joint Upstream	-178,587
Adjusted	4,769,550
Peak Demand (kW)	
Unadjusted	31,391.8
Joint Downstream	746.5
Joint Upstream	636.6
Adjusted	30,008.7

Figure 4-9. PG&E adjusted percentage electric and gas savings, program year 2018



5 SDG&E IMPACT RESULTS

5.1 Unadjusted electric and gas savings estimates

San Diego Gas & Electric (SDG&E) administers eight HER waves. Table 5-1 summarizes important features of each wave, including the launch date, report frequency, report medium, and fuel type. These features vary across waves and lead to variation in HER-related savings across waves. Importantly, SDG&E labels waves with "paper" or "digital", though these labels do not exactly correspond to the medium received by recipients in the wave. For example, 95% of recipients in Opower 3 Expansion Digital receive both paper and digital reports.

Table 5-1. SDG&E HER waves, program year 2018

Wave	Launch Date	Report Frequency	Report Medium	Fuel	Customer Counts	Initial Treatment Customers	Initial Control Customers
Opower 1	Jul-2011	Bi-monthly	100% paper	Dual	Electric	19,977	19,909
					Gas	19,977	19,909
Opower 2 Low Income	Nov-2014	Bi-monthly	10% paper, 1% email, 88% both	Dual, electric-only	Electric	26,018	7,074
					Gas	26,017	7,074
Opower 2 Non-Low Income	Nov-2014	Bi-monthly	2% paper, 2% email, 96% both	Dual, electric-only	Electric	57,175	15,850
					Gas	57,137	15,839
Opower 3 Expansion Digital	Jan-2016	Quarterly	40% paper, 2% email, 58% both	Dual, electric-only	Electric	265,902	24,687
					Gas	265,836	24,681
Opower 3 Expansion Paper	Jan-2016	Bi-monthly paper, monthly digital	3% paper, 1% email, 95% both	Dual, electric-only	Electric	195,670	24,697
					Gas	195,604	24,686
Opower 4 Digital	May-2017	Quarterly	38% paper, 62% both	Dual, electric-only	Electric	63,178	17,406
					Gas	63,171	17,402
Opower 4 Paper	May-2017	Bi-monthly paper, monthly digital	1% paper, 99% both	Dual, electric-only	Electric	48,753	13,893
					Gas	48,739	13,892
Opower 5	Dec-2017	Quarterly paper, monthly digital	44% paper, 56% both	Dual, electric-only	Electric	222,500	35,000
					Gas	222,500	35,000

Figure 5-1 and Figure 5-2 present the annual unadjusted electric and gas savings per recipient. The highest electric savings estimate comes from recipients in Opower 3 Expansion Paper. The highest gas savings estimate comes from recipients in Opower 1. Opower 3 Expansion Paper sent recipients both paper and digital reports at least once a month. Though it started a year later, Opower 4 Paper maintained that same targeting approach. Opower 5 started late in 2017, and savings levels are unlikely to reflect the higher savings levels they will reach in their 3rd or 4th year. Other characteristics listed in Table 5-1 likely explain the remaining variability in savings estimates.

Figure 5-1. SDG&E annual unadjusted electric savings per recipient, program year 2018

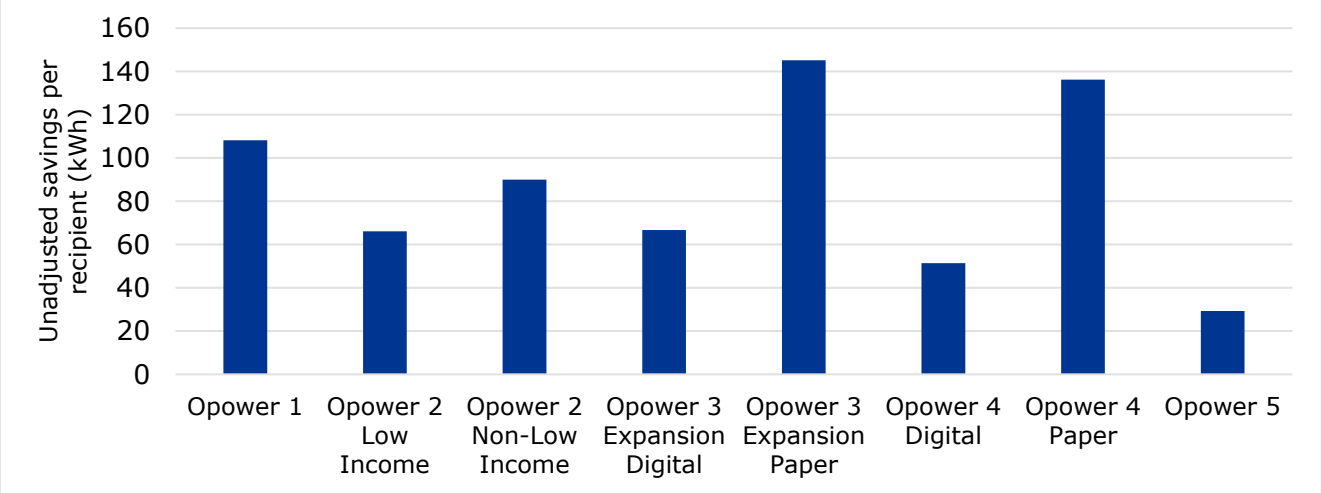


Figure 5-2. SDG&E annual unadjusted gas savings per recipient, program year 2018

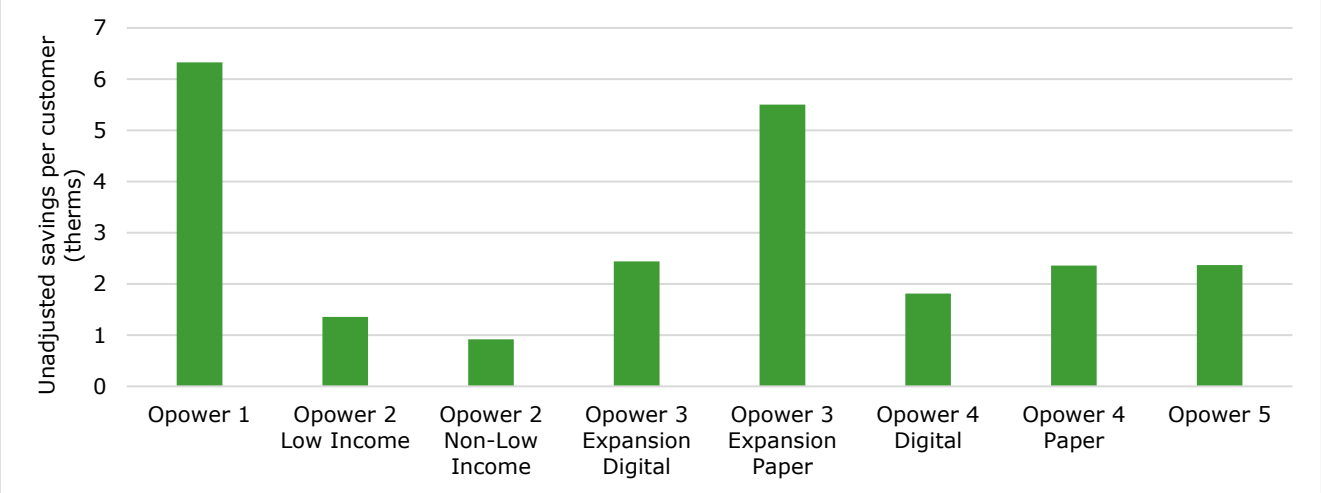


Table 5-2 provides tabular data for Figure 5-1 in the final column and related data for each wave, including baseline electricity use, number of customers in the treatment group, and savings magnitude in kWh at both per recipient and wave levels. SDG&E's HER recipients produced 51.5 MWh of unadjusted electric savings in 2018. Recipients in Opower 3 Expansion Paper have the highest baseline electricity use and the third highest savings per recipient as a percentage of baseline use. Recipients across waves saved between 0.7% and 1.7% of baseline electricity consumption.

Table 5-2. SDG&E total unadjusted electric savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Electric (kWh)							
Opower 1	8,416	11,907	108	1,287,627	37,004	2,538,250	1.3%
Opower 2 Low Income	5,536	14,700	66	971,775	-40,511	1,984,062	1.2%
Opower 2 Non-Low Income	5,151	32,373	90	2,912,199	1,414,598	4,409,800	1.7%
Opower 3 Expansion Digital	5,284	159,302	67	10,620,584	6,743,304	14,497,864	1.3%
Opower 3 Expansion Paper	9,758	148,911	145	21,608,736	13,573,036	29,644,437	1.5%
Opower 4 Digital	4,851	40,848	51	2,097,278	1,126,769	3,067,787	1.1%
Opower 4 Paper	8,461	38,928	136	5,302,619	3,261,570	7,343,667	1.6%
Opower 5	3,997	192,773	29	5,649,123	3,556,176	7,742,070	0.7%

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

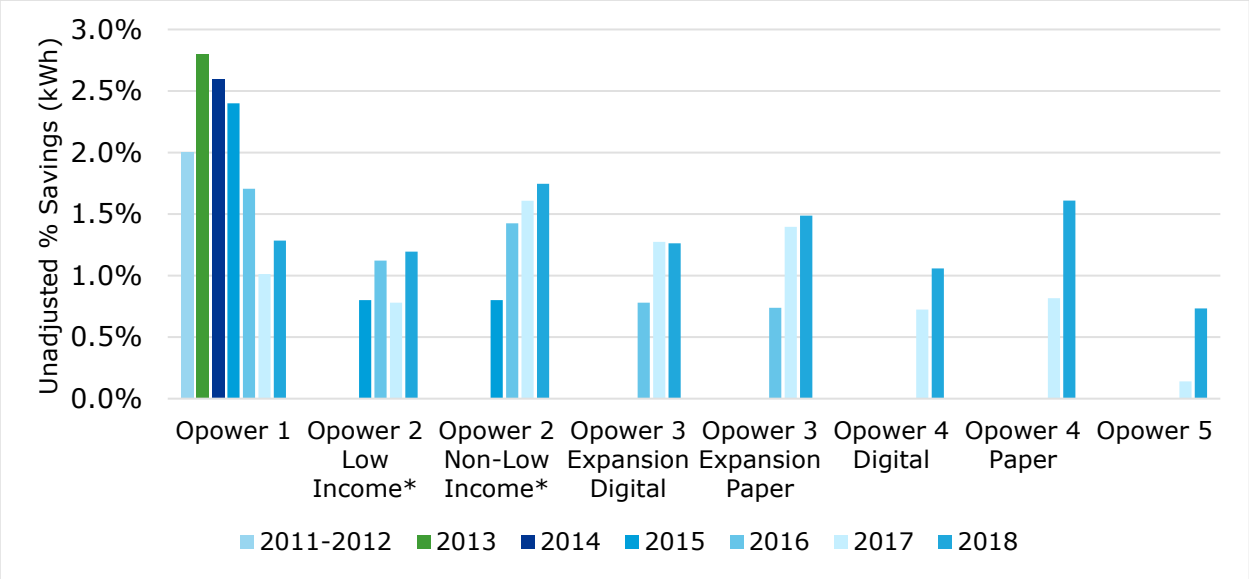
Table 5-3 provides percent savings, baseline gas use, the number of customers in the treatment group, and savings magnitude in therms at both per recipient and wave levels. SDG&E's HER recipients produced 1.2 million therms of unadjusted gas savings in 2018. Recipients across waves saved between 0.3% and 1.3% of baseline gas consumption.

Table 5-3. SDG&E total unadjusted gas savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Gas (therms)							
Opower 1	559	8,899	6	56,300	34,747	77,853	1.1%
Opower 2 Low Income	298	10,652	1	14,447	844	28,050	0.5%
Opower 2 Non-Low Income	287	23,072	1	21,184	-94	42,462	0.3%
Opower 3 Expansion Digital	295	106,570	2	259,942	189,684	330,200	0.8%
Opower 3 Expansion Paper	433	79,834	6	439,320	336,633	542,006	1.3%
Opower 4 Digital	277	24,567	2	44,505	25,338	63,671	0.7%
Opower 4 Paper	395	23,695	2	55,881	22,714	89,048	0.6%
Opower 5	249	123,229	2	291,958	233,010	350,906	1.0%

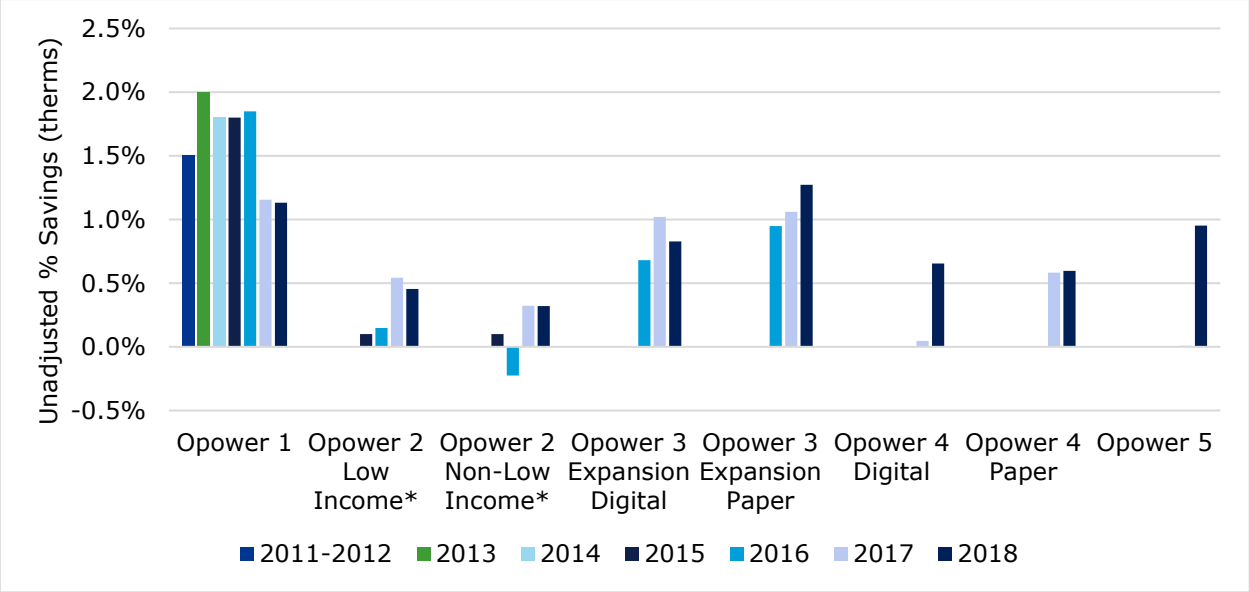
Figure 5-3 and Figure 5-4 present historical estimates of annual unadjusted electric and gas savings per recipient as a percentage of baseline use. The figures show that electric and gas savings increase for recipients in most waves after the first year of receiving HER. After several years this trend appears to plateau, after which there is year-to-year variability that reflects weather and other random differences. These trends and variability may support the idea that HER motivate SDG&E customers differently over time.

Figure 5-3. SDG&E unadjusted percent electric savings over time, program year 2018



*In 2015 Opower 2 savings were not split between low- and non-low-income sub-waves.

Figure 5-4. SDG&E unadjusted percent gas savings over time, program year 2018



*In 2015 Opower 2 savings were not split between low- and non-low-income sub-waves.

5.2 Unadjusted demand savings estimates

5.2.1 Heat waves

Table 5-4 presents the optimal heatwave (HW) for each SDG&E HER program year, as well as the optimal HW in the current evaluation year. Because SDG&E launched all waves before the optimal HW in 2018, recipients in every wave contribute to estimates of unadjusted peak demand savings for the current evaluation year.

Table 5-4. SDG&E DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2018 Post-Period
Opower 1	9/27/2010	-	9/29/2010	8/8/2018 - 8/10/2018
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	
Opower 4 Digital	9/26/2016	-	9/28/2016	
Opower 4 Paper	9/26/2016	-	9/28/2016	
Opower 5	8/30/2017	-	9/1/2017	

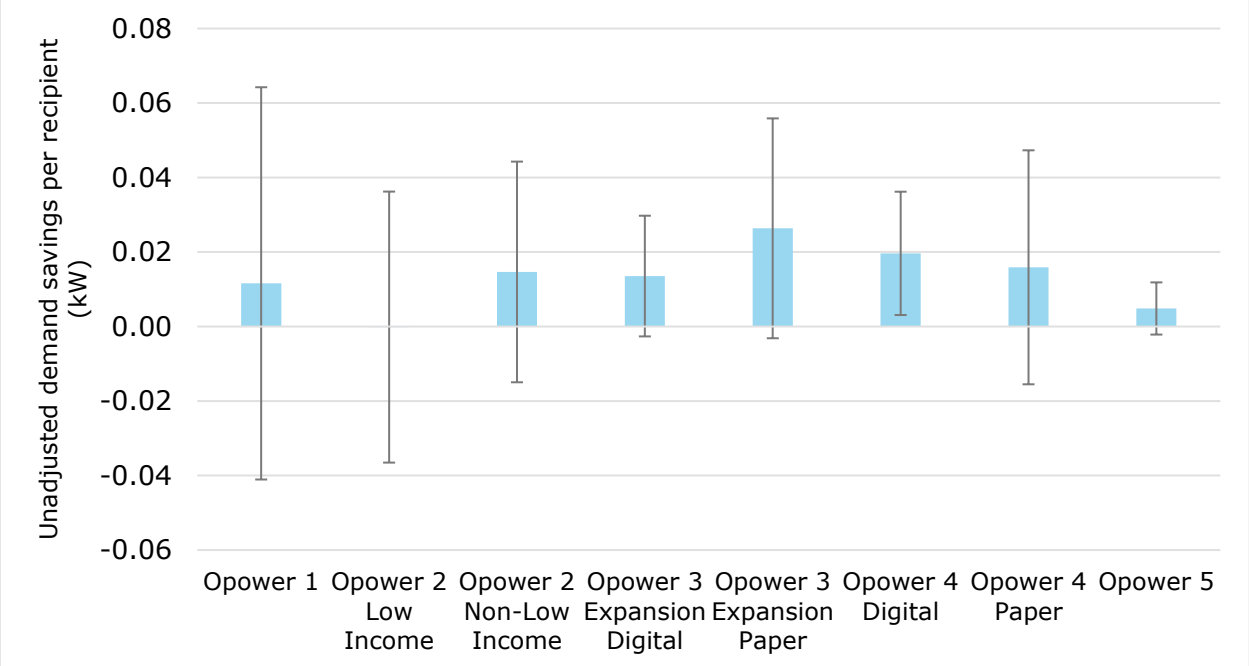
5.2.2 Peak demand savings

Table 5-5 shows SDG&E's HER recipients produced 8.8 MW of unadjusted peak demand savings in 2018. Figure 5-5 presents estimates of annual unadjusted peak demand savings per recipient. Recipients in Opower 3 Expansion Paper achieved the greatest peak demand savings.

Table 5-5. SDG&E total unadjusted peak demand savings, program year 2018

Wave	Active Accounts during Peak Period (Aug. 8 - Aug. 10, 2018)	Total Peak Demand Savings (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Opower 1	11,799	136.7	-484.5	757.9
Opower 2 Low Income	14,151	-2.1	-516.8	512.6
Opower 2 Non-Low Income	31,847	466.7	-476.6	1,410.0
Opower 3 Expansion Digital	155,406	2,105.4	-412.1	4,622.8
Opower 3 Expansion Paper	146,362	3,858.9	-460.6	8,178.5
Opower 4 Digital	38,935	764.7	120.2	1,409.2
Opower 4 Paper	37,729	599.8	-585.1	1,784.8
Opower 5	185,590	899.2	-401.0	2,199.5
Total	**621,819**	**8,829.4**	**-3,216.7**	**20,875.4**

Figure 5-5. SDG&E unadjusted annual peak demand savings per recipient, program year 2018



5.3 Downstream rebate joint savings

As shown in Table 5-6., SDG&E's HER recipients' participation in downstream rebate programs produced 388 MWh, 50,000 therms, and 0.9 MW of downstream joint savings in 2018.

Table 5-6. Total SDG&E downstream joint savings by wave, program year 2018

Wave	Electric (kWh)	Gas (therms)	Peak Demand (kW)
Opower 1	0	0	0
Opower 2 Low Income	84,727	2,290	0
Opower 2 Non-Low Income	0	0	0
Opower 3 Expansion Digital	0	0	0
Opower 3 Expansion Paper	148,370	41,033	203.5
Opower 4 Digital	0	2,455	0
Opower 4 Paper	0	4,143	81.8
Opower 5	155,140	0	644.4
Total	**388,237**	**49,920**	**929.7**

Figure 5-6 and Figure 5-7 present estimates of downstream annual joint electric and gas savings per recipient. Recipients in Opower 2 Low-Income produced the highest downstream joint electric savings; recipients in Opower 3 Expansion Paper produced the highest downstream joint gas savings. All estimates of downstream joint electric and gas savings remain statistically indistinguishable from zero savings (including negative estimates).

Figure 5-6. SDG&E downstream annual electric joint savings per recipient, program year 2018

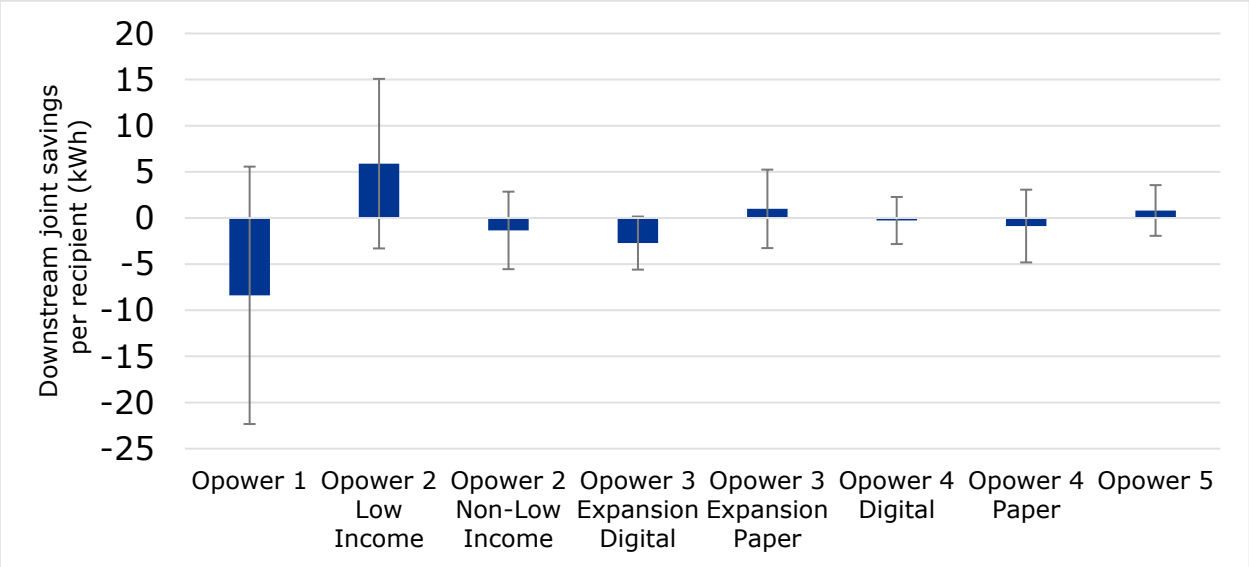


Figure 5-7. SDG&E downstream annual gas joint savings per recipient, program year 2018

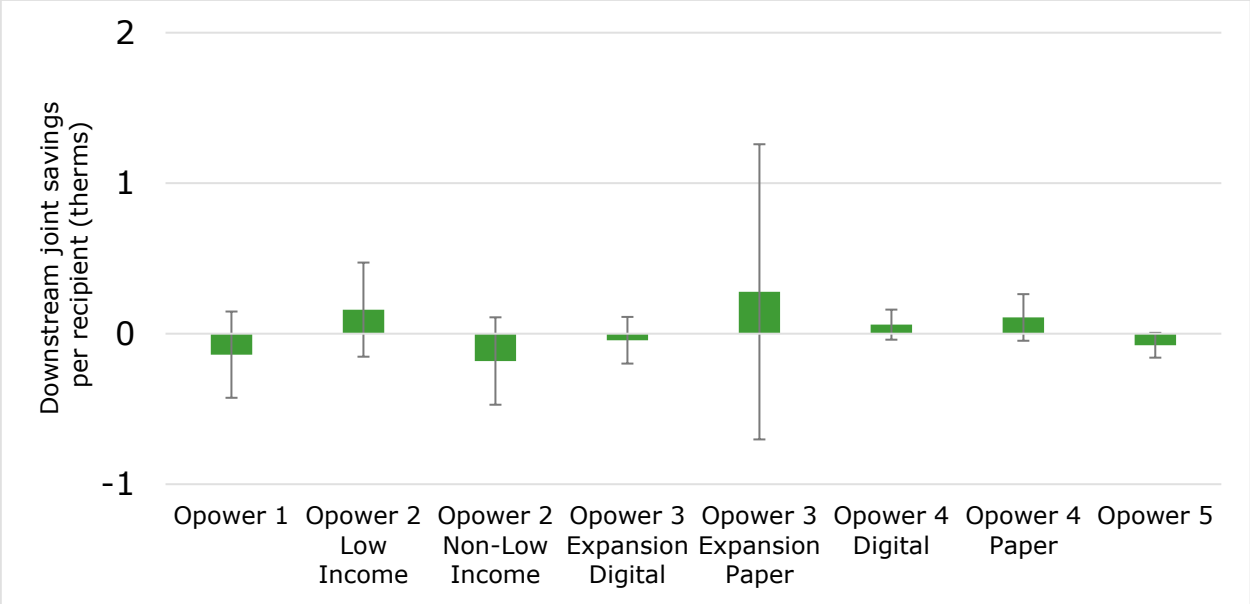
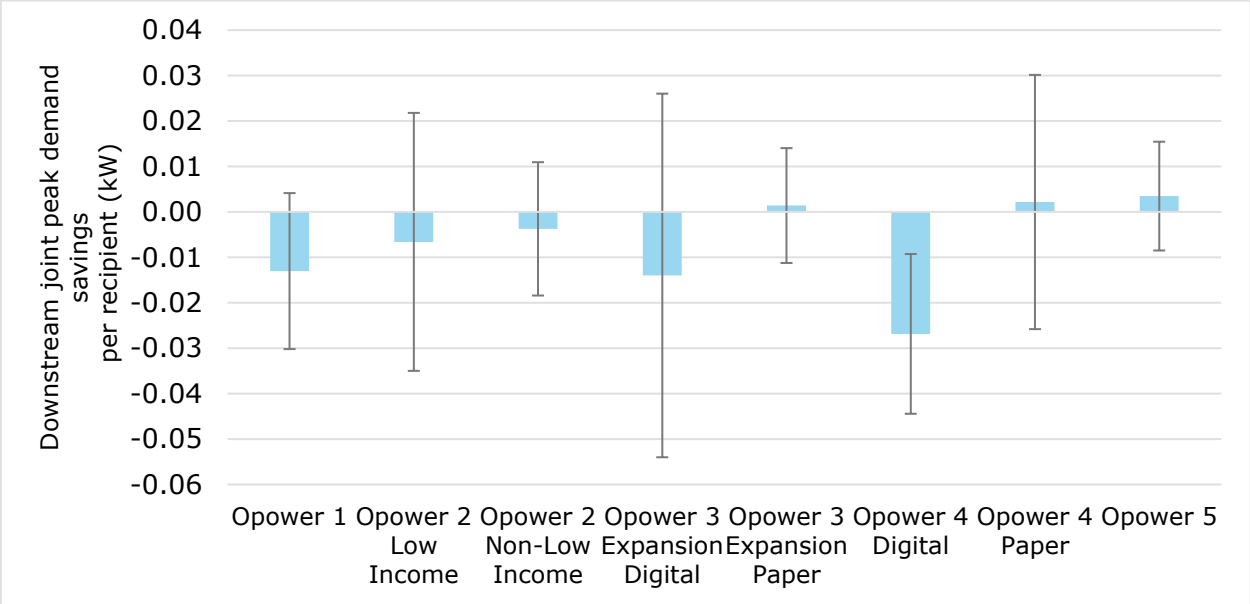


Figure 5-8 presents estimates of downstream annual joint peak demand savings per recipient. Recipients in Opower 5 produced the highest downstream joint peak demand savings. Even so, all estimates of downstream joint peak demand savings remain either statistically indistinguishable from zero savings or negative.

Figure 5-8. SDG&E downstream annual peak demand joint savings per recipient, program year 2018



5.4 Upstream rebate joint savings

Table 5-7. presents estimates of upstream annual joint savings per recipient. SDG&E's HER recipients produced 312 MWh and 0.017 MW of upstream joint savings in 2018 (Table 5-8). Appendix G presents the PA-specific inputs to the upstream calculations.

Recipients in Opower 2 through Opower 4 produced notable joint electric negative savings for both bulb types, while recipients in Opower 1 produced the highest upstream joint savings. Also, the analysis produced near-zero estimates for upstream joint peak demand savings. These results are consistent with peak demand periods occurring when lighting demand is low.

Table 5-7. SDG&E upstream annual joint savings per recipient, program year 2018

Wave	Upstream Joint Savings per Recipient per Year				
	Electric (kWh)			Interactive Effects (therms)	Peak Demand (kW)
	CFL	LED	Total		
Opower 1	9	7	17	>-1	<0.1
Opower 2	>-1	-2	0	0	0
Opower 3	-2	-12	0	0	0
Opower 4	>-1	-3	0	0	0
Opower 5	<1	<1	<1	>-1	<0.1
Total	**6**	**-9**	**17**	**0**	**<0.1**

Table 5-8. SDG&E total upstream joint savings by wave, program year 2018

Wave	Total Upstream Joint Savings		
	Electric (kWh)	Interactive Effects (therms)	Peak Demand (kW)
Opower 1	198,678	-2,904	15
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
Opower 4 Digital	0	0	0
Opower 4 Paper	0	0	0
Opower 5	113,761	-2,346	2
Total	**312,439**	**-5,250**	**17**

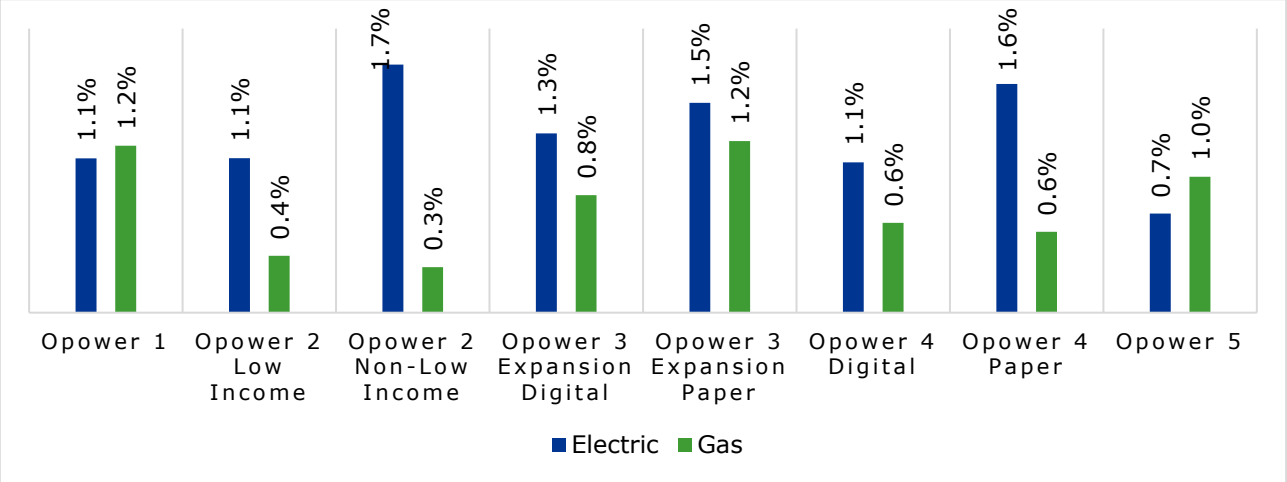
5.5 Total (adjusted) program savings

Table 5-9. presents the total (adjusted) savings for SDG&E's HER program in 2018, while Appendix D presents figures that show the relative magnitude of the downstream and upstream joint savings adjustments. Figure 5-9 compares adjusted HER program electric and gas savings as a percentage of baseline energy use.

Table 5-9. SDG&E total savings for the 2018 HER program

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	50,449,942
Joint Downstream	388,237
Joint Upstream	312,439
Adjusted	49,749,265
Gas (therms)	
Unadjusted	1,183,537
Joint Downstream	49,920
Joint Upstream	-5,250
Adjusted	1,138,867
Peak Demand (kW)	
Unadjusted	8,829.4
Joint Downstream	929.7
Joint Upstream	16.8
Adjusted	7,885.0

Figure 5-9. SDG&E percentage electric and gas savings by wave, program year 2018



6 SCE IMPACT RESULTS

6.1 Unadjusted electric savings estimates

Southern California Edison (SCE) administers six HER waves. Table 6-1. SCE HER waves summarizes important features of each wave, including the launch date and the target group. These features vary across waves and lead to variation in HER-related savings across waves. All HER participants receive printed HERs quarterly and emailed HERs monthly. Emails are sent to participants with available email addresses.

Table 6-1. SCE HER waves, program year 2018

Wave	Launch Date	Target Group	Fuel	Initial Treatment	Initial Control
Opower 2	Mar-2014	High Usage Single Family Homes in San Gabriel Valley and Rancho Cucamonga Area	Electric-only	75,000	75,000
Opower 3	Sep-2015	High Usage Single Family Homes in Climate Zones 8, 9, 10, 14	Electric-only	164,800	50,315
Opower 4	Apr-2016	High Usage Single Family Homes	Electric-only	265,650	37,107
Opower 5	Apr-2017	High Usage Single Family Homes	Electric-only	602,712	50,104
Opower 6	Apr-2018	Single family population	Electric-only	446,640	44,961
Opower 7	Sep-2018	Single family population	Electric-only	357,487	48,671

Figure 6-1 presents the annual unadjusted electric savings per recipient. The highest estimates of electric savings came from recipients in Opower 4. SCE targeted high usage recipients for the Opower 2 through Opower 5 and targeted broader populations for Opower 6 and Opower 7.

Figure 6-1. SCE annual unadjusted electric savings per recipient, program year 2018

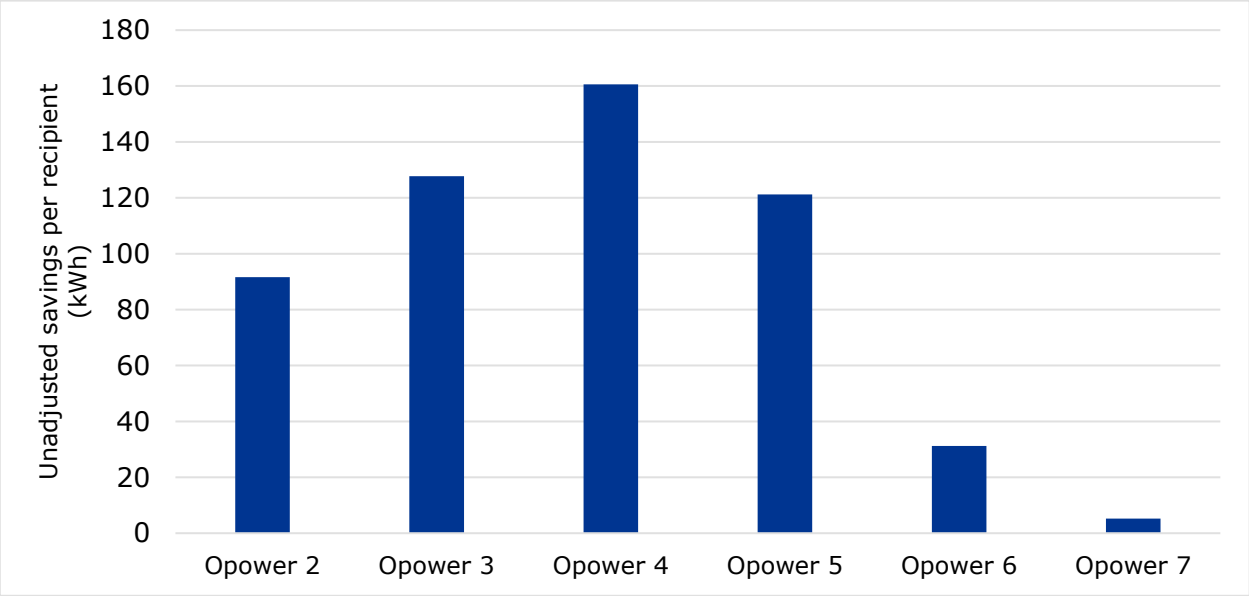


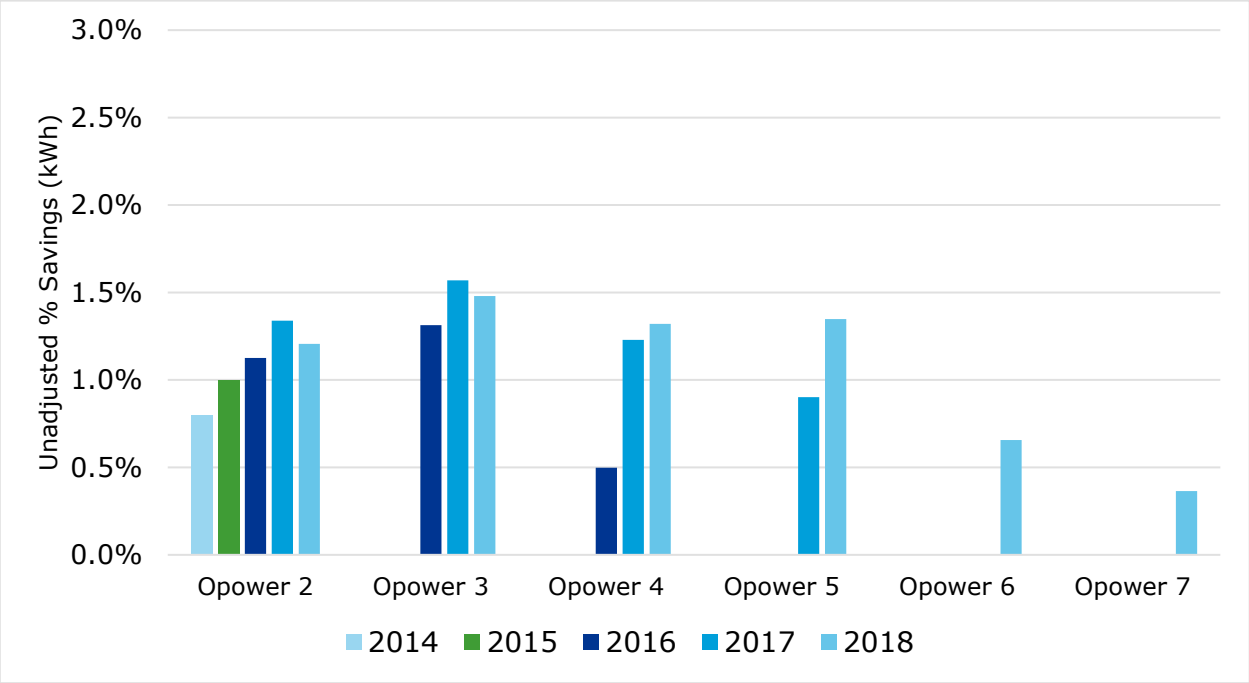
Table 6-2. summarizes baseline electricity use, the number of customers in the treatment group, and savings magnitude in kWh at both per recipient and wave levels. SCE's HER recipients produced 133 MWh of unadjusted electric savings. In 2018, recipients across the waves saved between 0.4% and 1.5% of baseline electricity consumption.

Table 6-2. SCE total unadjusted electric savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Electric (kWh)							
Opower 2	7,593	59,133	92	5,417,503	4,134,425	6,700,580	1.2%
Opower 3	8,634	134,031	128	17,124,695	14,186,394	20,062,995	1.5%
Opower 4	12,163	205,473	161	32,993,699	25,641,291	40,346,107	1.3%
Opower 5	8,993	513,762	121	62,279,553	52,984,309	71,574,797	1.3%
Opower 6	4,752	417,826	31	13,040,336	9,407,908	16,672,763	0.7%
Opower 7	1,429	331,237	5	1,727,626	497,334	2,957,919	0.4%

Figure 6-2 presents estimates of annual unadjusted electric savings as a percentage of baseline use. The figure shows that recipients in Opower 2 through Opower 5 increased electric savings after the first year. There is year-to-year variability that reflects weather and other random differences.

Figure 6-2. SCE unadjusted percentage electric savings over time, program year 2018



6.2 Unadjusted demand savings estimates

6.2.1 Heat waves

Table 6-3. presents the optimal heatwave (HW) for each SCE HER program year, as well as the optimal HW in the current evaluation year. Because SCE did not launch Opower 7 until after the optimal HW in 2018, recipients in in Opower 7 do not contribute to estimates of peak demand savings for the current evaluation year.

Table 6-3. SCE DEER Heatwaves

Wave	DEER Heatwave			
	Pre-Period			2018 Post-Period
Opower 2	9/4/2013	-	9/6/2013	7/23/2018 - 7/25/2018
Opower 3	9/15/2014	-	9/17/2014	
Opower 4	8/26/2015	-	8/28/2015	
Opower 5	7/20/2016	-	7/22/2016	
Opower 6	8/30/2017	-	9/1/2017	

6.2.2 Peak demand reductions

SCE's HER recipients produced 29 MW of unadjusted peak demand savings in 2018 (Table 6-4.). Figure 6-3 presents estimates of annual unadjusted peak demand savings per recipient. Recipients in Opower 4 achieved the greatest peak demand savings. Analysts verified positive estimates of unadjusted peak demand savings with 90% confidence for each SCE wave.

Figure 6-3. SCE unadjusted annual peak demand savings per recipient, program year 2018

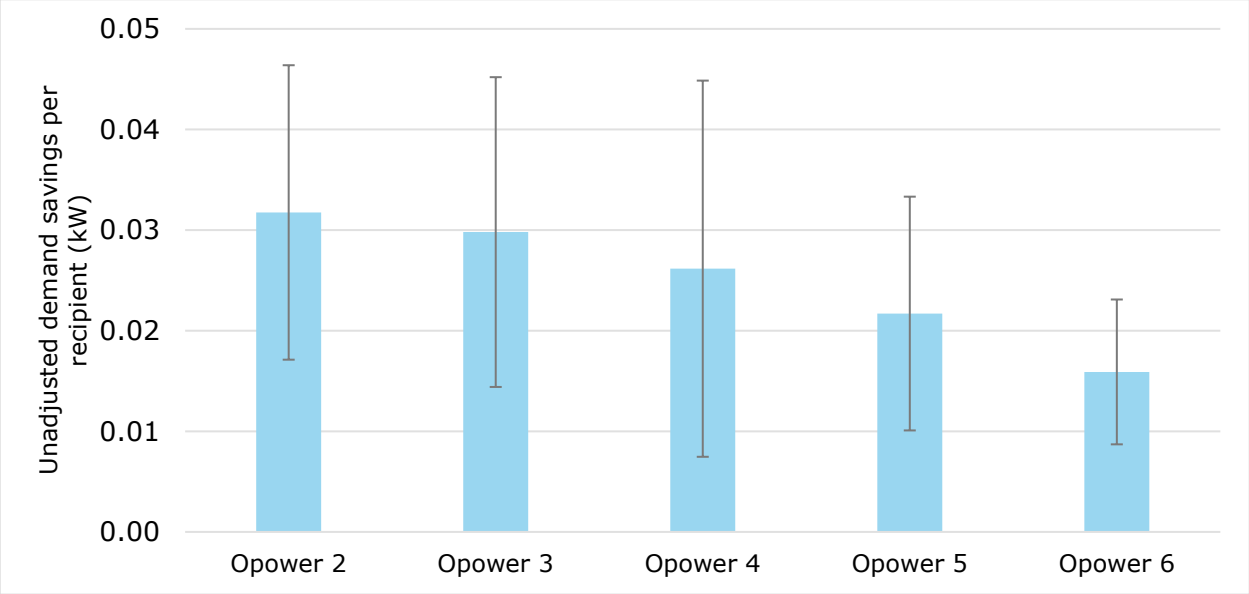


Table 6-4. SCE total unadjusted peak demand savings, program year 2018

Wave	Active Accounts during Peak Period (Jul. 23 - Jul. 25, 2018)	Total Peak Demand Savings (kW)	Lower Bound 90% CI	Upper Bound 90% CI
Opower 2	59,026	1,874.2	1,010.5	2,738.0
Opower 3	133,719	3,985.2	1,926.6	6,043.8
Opower 4	205,268	5,370.3	1,533.0	9,207.6
Opower 5	511,920	11,111.7	5,164.7	17,058.7
Opower 6	426,367	6,780.4	3,711.1	9,849.6
Total	**1,336,300**	**29,121.9**	**13,345.9**	**44,897.8**

6.3 Downstream rebate joint savings

Table 6-5. shows that SCE's HER recipients' participation in downstream rebate programs produced 912 MWh and 0.22 MW of downstream joint savings in 2018. Figure 6-4 presents estimates of downstream annual joint electric savings per recipient. Recipients in Opower 2 had the highest downstream joint savings. Most estimates of downstream joint electric savings remain statistically indistinguishable from zero electric savings (including negative estimates).

Table 6-5. SCE total downstream joint savings by wave, program year 2018

Wave	Electric (kWh)	Peak Demand (kW)
Opower 2	234,224	88.5
Opower 3	85,562	92.8
Opower 4	277,427	36.4
Opower 5	314,764	0
Opower 6	0	0
Opower 7	0	NA
Total	**911,977**	**217.8**

Figure 6-4. SCE downstream annual joint electric savings per recipient, program year 2018

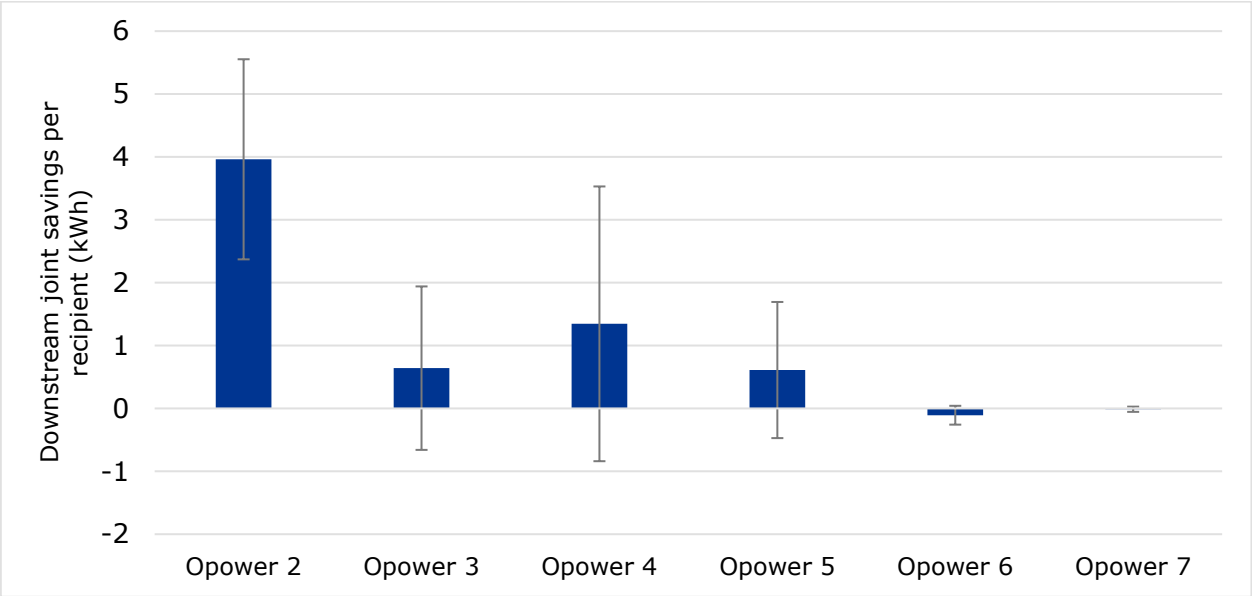
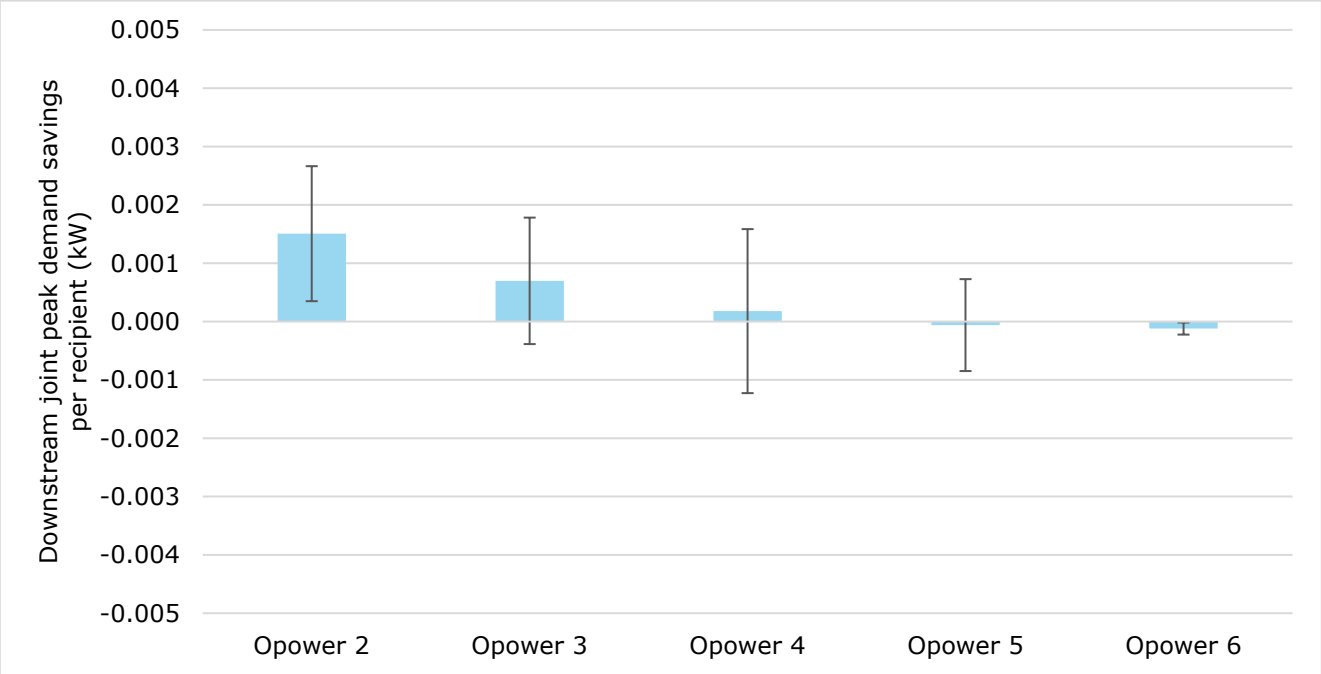


Figure 6-5 presents estimates of annual joint peak demand savings per recipient. Recipients in Opower 2 had the highest downstream joint savings. Most estimates of downstream joint electric savings remain statistically indistinguishable from zero electric savings (including negative estimates).

Figure 6-5. SCE downstream annual peak demand joint savings per recipient, program year 2018



6.4 Upstream rebate joint savings

Table 6-6. presents estimates of upstream annual joint savings per recipient. SCE's HER recipients produced 3,776 MWh and 0.28 MW of upstream joint savings in 2018 (Table 6-7.). Appendix G presents the PA-specific inputs to the upstream calculations.

The contribution to upstream joint savings from CFLs and LEDs varies across waves. These results support the idea that HERs exert a range of effects on joint electric savings with the Upstream Lighting Program, depending on wave features as well as lamp type. Also, analysts produced near-zero estimates for upstream joint peak demand savings. These results are consistent with peak demand periods occurring when lighting demand is low.

Table 6-6. SCE upstream annual joint savings per recipient, program year 2018

Wave	Upstream Joint Savings per Recipient per Year				
	Electric (kWh)			Interactive Effects (therms)	Peak Demand (kW)
	CFL	LED	Total		
Opower 2	30	2	32	-3	<1
Opower 3	16	-2	14	-1	<1
Opower 4	-23	9	0	0	0
Opower 5	-2	<1	0	0	0
Opower 6	>-1	<1	0	0	0
Opower 7	>-1	<1	0	0	NA
Total	**19**	**10**	**46**	**-4**	**<1**

Table 6-7. SCE total upstream joint savings by wave, program year 2018

Wave	Total Upstream Joint Savings	
	Electric (kWh)	Peak Demand (kW)
Opower 2	1,883,635	137.6
Opower 3	1,892,448	139.2
Opower 4	0	0
Opower 5	0	0
Opower 6	0	0
Opower 7	0	NA
Total	**3,776,083**	**276.9**

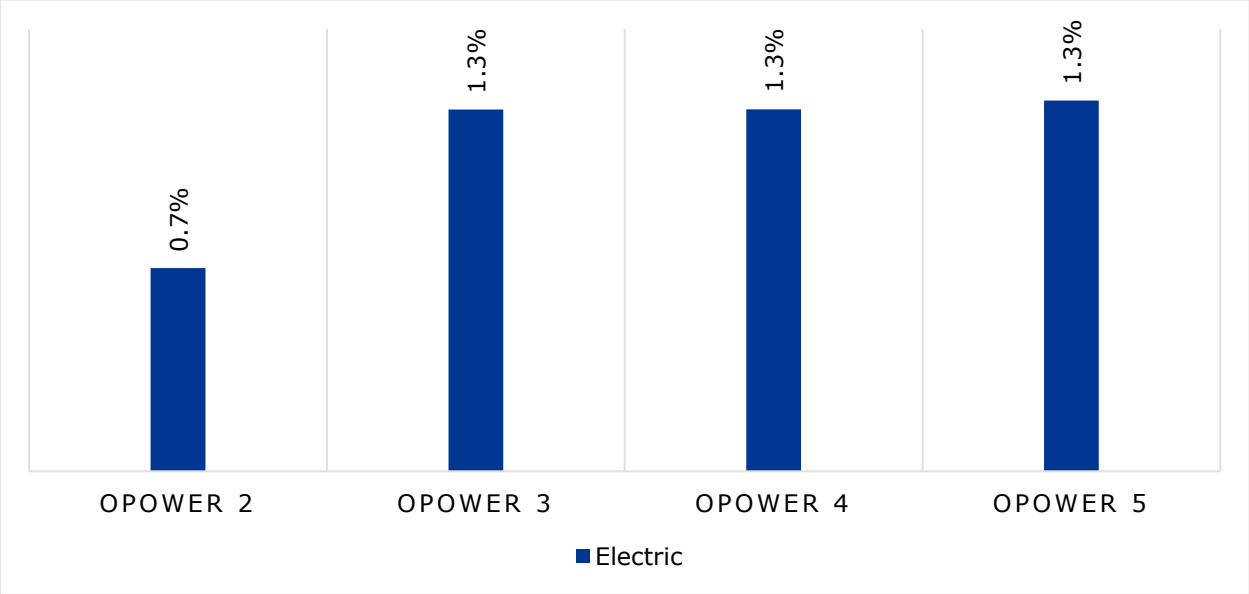
6.5 Total (adjusted) program savings

Table 6-8. presents total (adjusted) savings for SCE's HER program in 2018, while Appendix D presents figures that show the relative magnitude of the downstream and upstream joint savings adjustments. Figure 6-6 presents HER program electric savings as a percentage of baseline electricity use.

Table 6-8. SCE total savings for the 2018 HER program

Type of Savings	Total Program Savings
Electric (kWh)	
Unadjusted	132,583,411
Joint Downstream	911,977
Joint Upstream	3,776,083
Adjusted	127,895,352
Peak Demand (kW)	
Unadjusted	29,121.9
Joint Downstream	217.8
Joint Upstream	276.9
Adjusted	28,627.2

Figure 6-6. SCE percentage electric savings by wave, program year 2018



7 SCG IMPACT RESULTS

7.1 Unadjusted gas savings estimates

Southern California Gas Company (SCG) currently administers seven HER waves. SCG launched its HER program in conjunction with its Advanced Meter (AMI) Project in 2013 with a commitment to achieve 1% gas savings due to HERs. First, SCG determined which customers would be eligible to receive HERs. They were required to have: 1) a fully functioning advanced meter; 2) enough gas consumption to belong in the two highest consumption quartiles; and 3) 13 months of billing history. Second, SCG segmented eligible customers by previous gas consumption, sensitivity to weather, eligibility status for low-income programs, and participation in SCG's online services. The segmentation led to 50 mutually exclusive treatment groups by the end of 2017. After the Advanced Meter Project concluded in November 2017, SCG transitioned the HER program to its energy efficiency portfolio.

There are several details about SCG's HER customers to understand. First, SCG randomly selected and reassigned control group customers from earlier years to new treatment and control groups for the 2018 program year. Second, SCG removed a set of low-income customers from existing treatment and control groups after they accidentally assigned those customers to later low-income treatment and control groups. Third, DNV GL split the aggregated groups that formed Wave 6 because the aggregated treatment groups did not share the same control group. DNV GL vetted all changes in SCG's experimental designs and believes they continue to produce valid estimates.

DNV GL provides two separate set of results for SCG's HER program in this evaluation. The first set of results reflect HER activity to verify SCG's claimed savings and cover November 2017 to October 2018. The second set reflect activity in calendar year 2018 covering January 2018 to December 2018 to compare savings to those from other PAs.

Table 7-1 summarizes some important features of each wave, including the launch date, the implementer, the target group, and the fuel type. These features vary across waves and lead to variation in HER-related savings across waves.

Table 7-1. SCG HER waves, program year 2018 (November 2017-October 2018)

Wave	Launch Date	Implementer	Target Group	Fuel	Initial Treatment Customers	Initial Control Customers
Wave 1	Nov-2015	Opower, SCG	Top-two energy use quartiles with My Account	Gas-only	182,500	74,202
Wave 2	Nov-2015	Opower	Top-two energy use quartiles without My Account	Gas-only	124,100	63,194
Wave 3	Nov-2015	Opower	Top-two energy use quartiles with CARE status	Gas-only	41,250	27,500
Wave 4	Nov-2016	Opower, Javelin, SCG	Top-two energy use quartiles with My Account	Gas-only	164,640	50,000
Wave 5	Nov-2016	Opower, Javelin	Top-two energy use quartiles without My Account	Gas-only	276,800	50,000
Wave 6a	Nov-2016	Opower, Javelin	Top-two energy use quartiles with CARE status	Gas-only	52,500	46,084
Wave 6b	Nov-2016	Opower, Javelin	Top-two energy use quartiles with CARE status	Gas-only	19,250	13,612

Figure 7-1 presents the annual (program year) unadjusted gas savings per recipient. The highest gas savings come from recipients in Wave 4 and Wave 6b. Wave 4 through Wave 6b employ the same targeting strategies as Wave 1 through Wave 3 respectively, though they launched one year later. Wave 1 and Wave 4 target recipients who use the online service "My Account", while Wave 2 and Wave 5 target recipients who do not use that service. Wave 3 and Wave 6a and 6b target recipients with CARE status. Other wave characteristics listed in Table 7-1. SCG HER waves likely explain the remaining variability in savings estimates.

Figure 7-1. SCG annual unadjusted gas savings per recipient, program year 2018

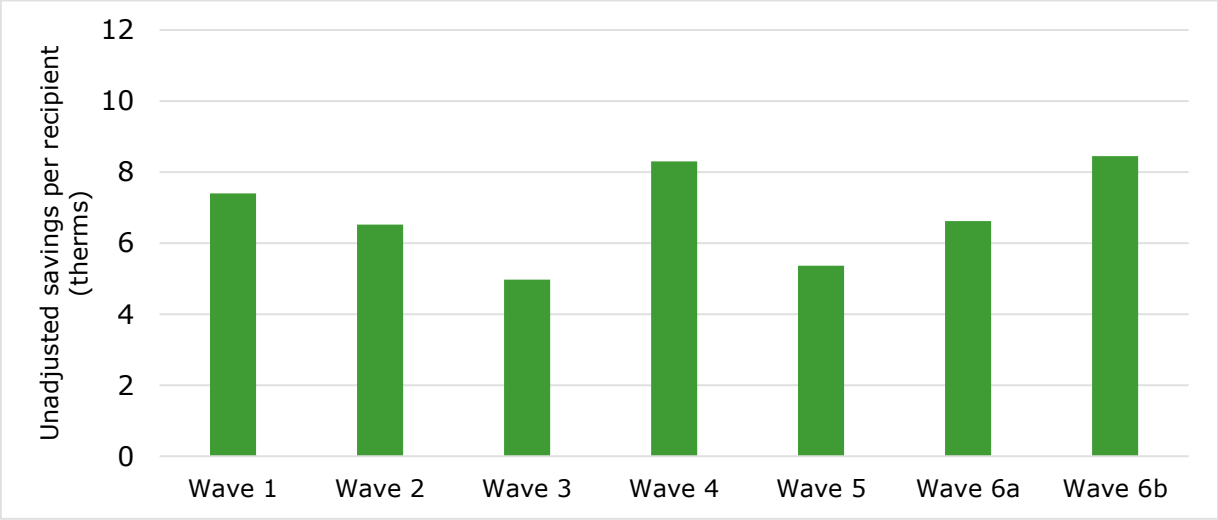


Figure 7-2 presents the annual (calendar year) unadjusted gas savings per recipient. The highest estimates of gas savings come from recipients in Wave 1 and Wave 6b.

Figure 7-2. SCG annual unadjusted gas savings per recipient, calendar year 2018

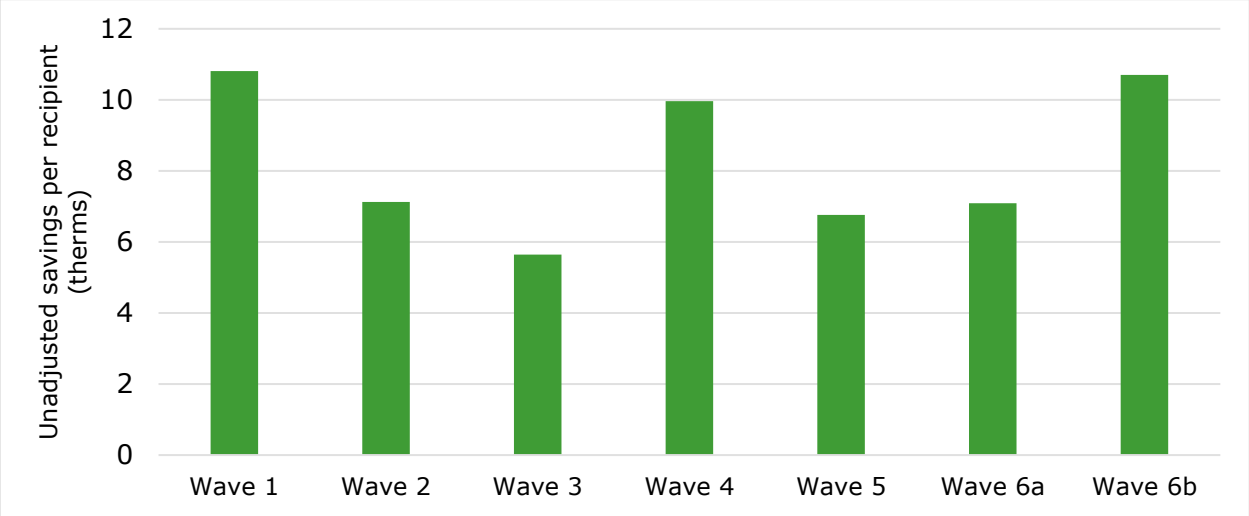


Table 7-2. summarizes baseline gas use, the number of customers in the treatment group, and gas savings at per recipient and wave levels. SCG's HER recipients produced 4,717,191 therms of unadjusted gas savings in program year 2018. Recipients across waves saved between 1.1% and 1.7% of baseline gas consumption.

Table 7-2. SCG total unadjusted gas savings, program year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Gas (therms)							
Wave 1	459	142,372	7	1,053,787	854,891	1,252,682	1.6%
Wave 2	464	104,208	7	679,740	526,972	832,509	1.4%
Wave 3	454	25,109	5	124,866	70,589	179,142	1.1%
Wave 4	490	143,841	8	1,194,109	944,056	1,444,162	1.7%
Wave 5	477	247,728	5	1,328,841	967,433	1,690,249	1.1%
Wave 6a	469	36,364	7	240,740	184,898	296,583	1.4%
Wave 6b	484	11,256	8	95,108	59,154	131,062	1.7%

Table 7-3 shows that SCG's HER recipients produced 5,749,019 therms of unadjusted gas savings in calendar year 2018. Recipients across waves saved between 1.2% and 2.2% of baseline gas consumption.

Table 7-3. SCG total unadjusted gas savings, calendar year 2018

Wave	Baseline Energy Use	Average Treatment Group Customers	Unadjusted Savings				
			Per Cust. per Year	Total	Lower Bound 90% CI	Upper Bound 90% CI	Percent Savings
Gas (therms)							
Wave 1	485	138,497	11	1,497,177	854,891	1,252,682	2.2%
Wave 2	486	102,079	7	727,382	526,972	832,509	1.5%
Wave 3	467	24,291	6	137,067	70,589	179,142	1.2%
Wave 4	512	139,862	10	1,393,527	944,056	1,444,162	1.9%
Wave 5	502	240,922	7	1,629,165	967,433	1,690,249	1.3%
Wave 6a	483	35,157	7	249,234	184,898	296,583	1.5%
Wave 6b	508	10,790	11	115,465	59,154	131,062	2.1%

Figure 7-3 presents estimates of annual (program year) unadjusted gas savings per recipient as a percentage of baseline use. DNV GL first evaluated each of the seven waves for the first time in program year 2018, so these percentage savings represent the most recent years' percentage savings for each wave though some of them started as three years earlier.

Figure 7-3. SCG unadjusted percentage gas savings, program year 2018

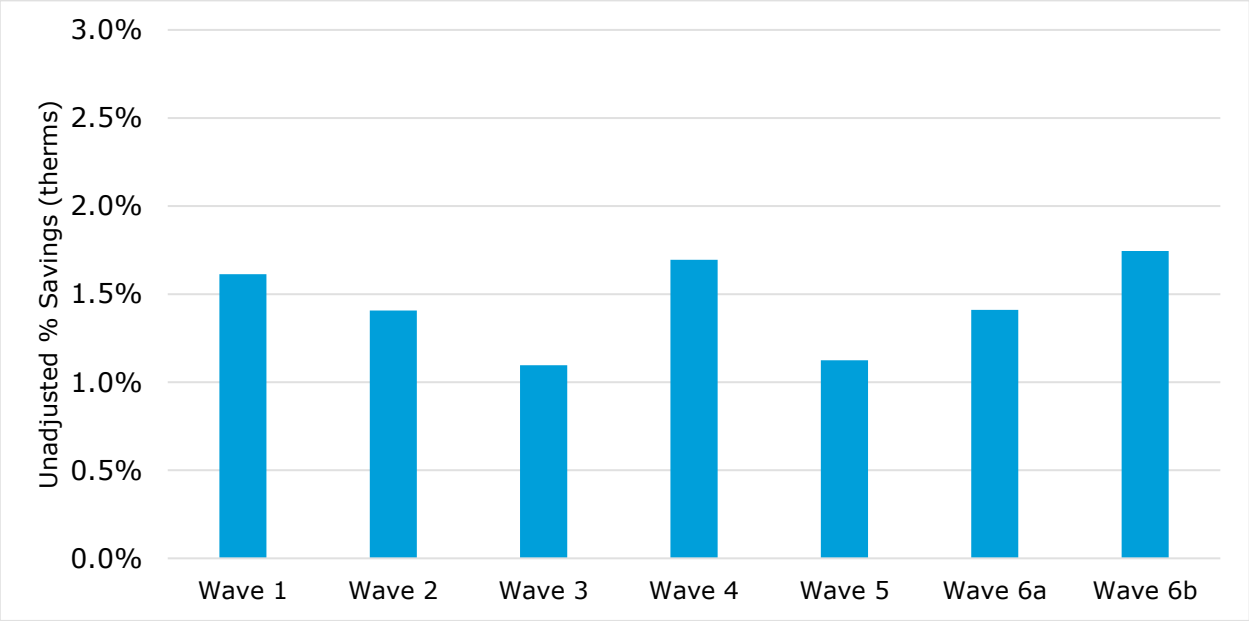
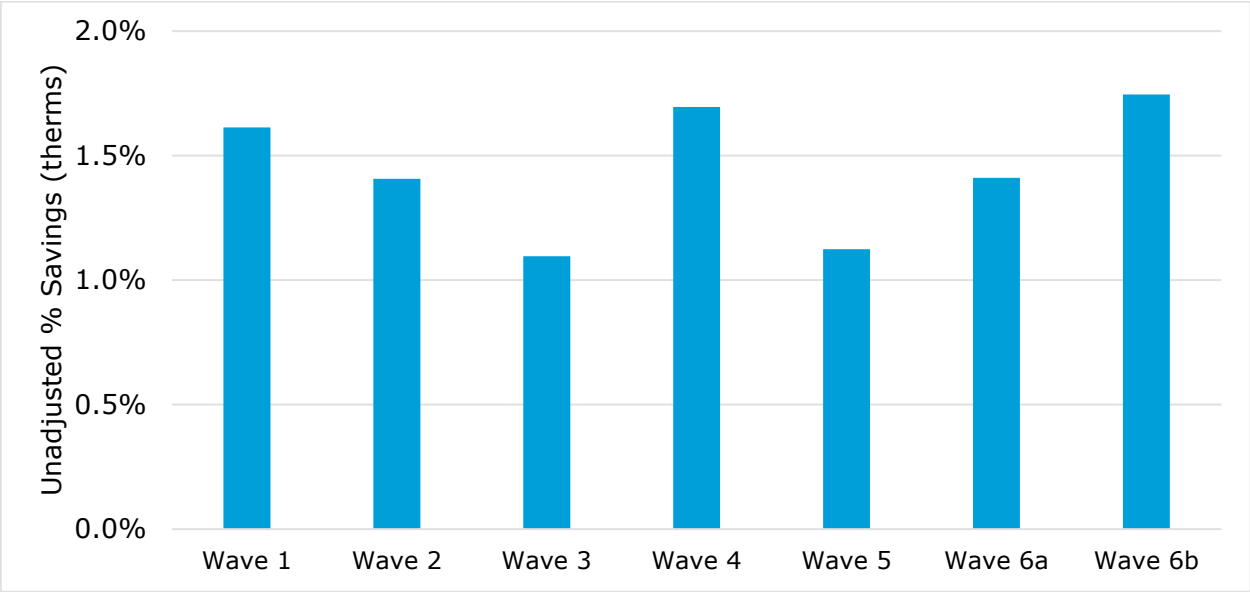


Figure 7-4 presents estimates of annual (calendar year) unadjusted gas savings as a percentage of baseline use. Again, these savings represent the most recent year's savings only.

Figure 7-4. SCG unadjusted percentage gas savings, calendar year 2018



7.2 Downstream rebate joint savings

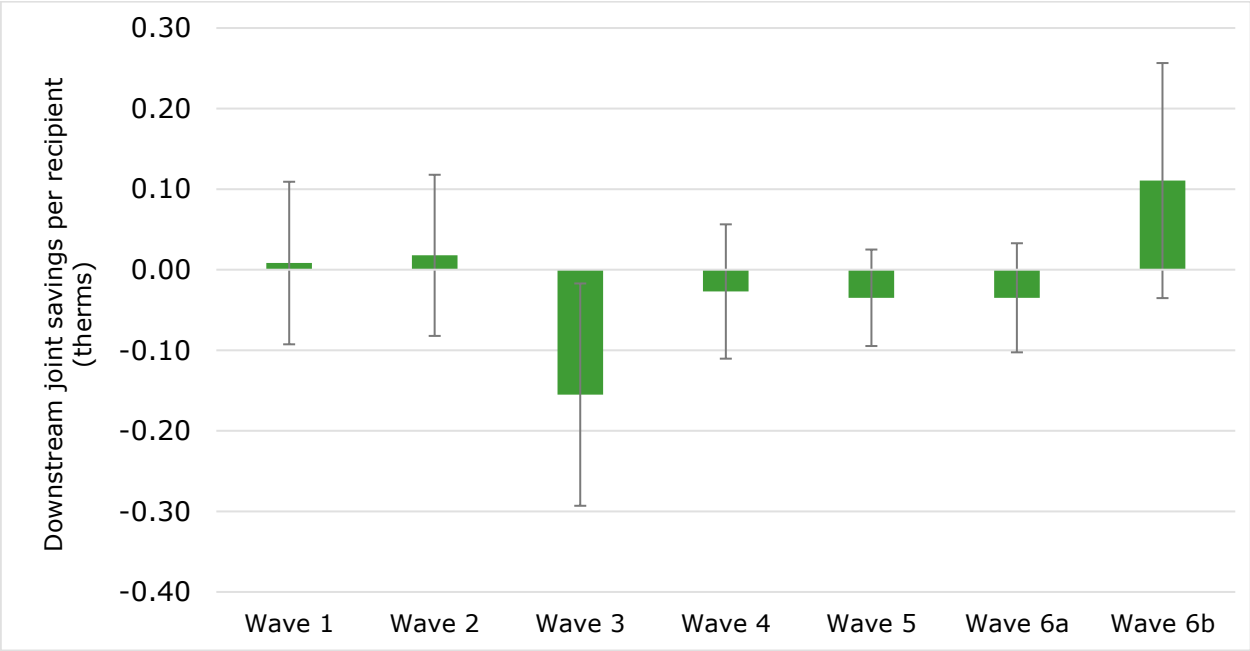
Table 7-4. indicates that SCG's HER recipients do not have downstream joint savings in program year 2018.[24] Figure 7-5 presents estimates of downstream annual (program year) joint gas savings per recipient. Recipients in most waves produced negative downstream joint gas savings. Most estimates of downstream joint gas savings remain statistically indistinguishable from zero.

Table 7-4. SCG total downstream joint savings by wave, program year 2018

Wave	Gas (therms)
Wave 1	1,199
Wave 2	1,827
Wave 3	-5,135
Wave 4	-3,906
Wave 5	-8,547
Wave 6a	-1,575
Wave 6b	1,867
Total	**-14,269**

[24] DNV GL calculated the joint downstream savings only for the program and not the calendar year. Calendar year adjusted results will use the program year downstream joint savings estimates to allow comparison to other PAs.

Figure 7-5. SCG downstream annual joint gas savings per recipient, program year 2018



7.3 Total (adjusted) program savings

Table 7-5 presents the total (adjusted) savings for SCG's HER program year and calendar year 2018, while Appendix D presents figures that show the relative magnitude of the downstream and upstream joint savings adjustments. Figure 7-6 and Figure 7-7 present adjusted HER program gas savings as a percentage of baseline gas use.

Table 7-5. SCG total savings for the 2018 HER program

Type of Savings	Total Program Year Savings	Total Calendar Year Savings
Gas (therms)		
Unadjusted	4,717,191	5,749,019
Joint Downstream	4,894	4,894
Joint Upstream	NA	NA
Adjusted	4,712,298	5,744,125

Figure 7-6. SCG percentage gas savings by wave, program year 2018

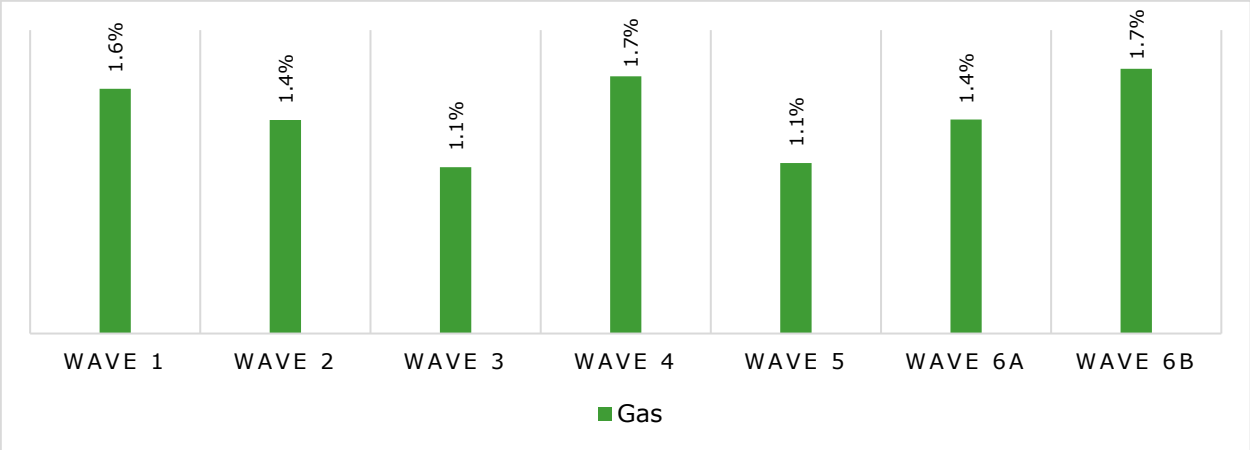
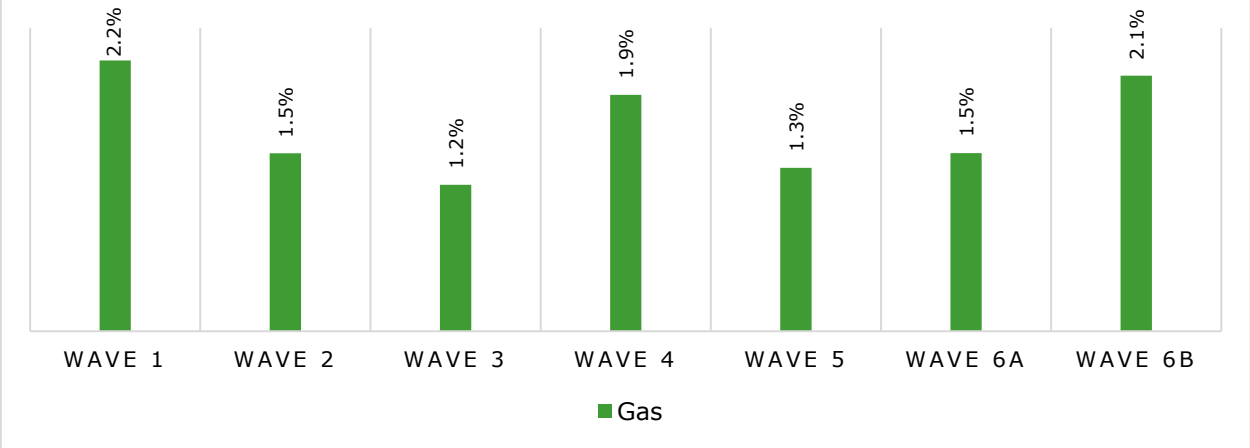


Figure 7-7. SCG percentage gas savings by wave, calendar year 2018

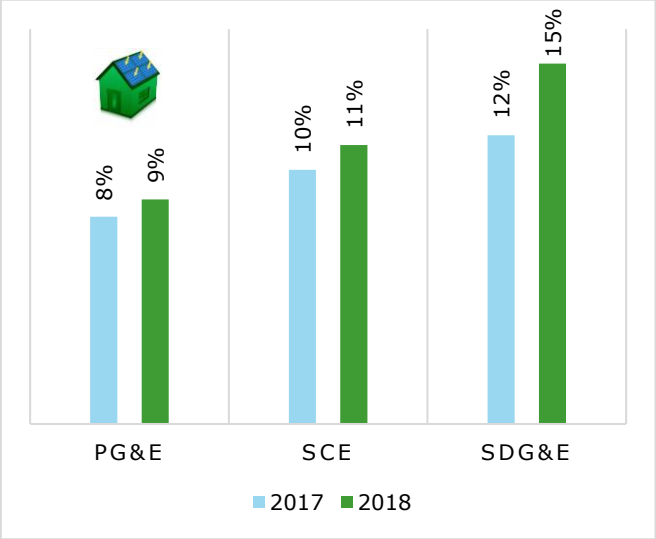


8 SOLAR PV ADOPTION

Customer adoption of rooftop solar photovoltaic (PV) is increasing in California. The data used for this evaluation reflect this trend. Solar adoption across all HER customers showed an increase of 1% to 3% for all PAs from 2017 to 2018. For instance, solar adoption among SDG&E's HER customers increased from 12% in 2017 to 15% in 2018 (Figure 8-1).

The increasing trend of solar use carries weight for future HER program evaluations because billing data provide household energy consumption that is net of household self-generation. This increase is currently equally prevalent among HER treatment and control group customers in all PAs. If there are different levels of adoption of solar or installations of differently sized solar panels between treatment and control group customers, the estimated program savings will be biased. For example, if because of HER the two groups adopt differently sized solar panels or have different rates of solar adoption, the difference in the actual energy consumption between them would vary from the difference if measured using only their utility sourced energy consumption. This would result in HER treatment effects that are not accurately measured. Thus, it is increasingly important to have data on on-site generation to get clearer visibility into the energy consumption of households to ensure unbiased estimates of HER program savings.

Figure 8-1. Prevalence of rooftop solar among HER customers in 2017 and 2018



9 EXPLORATORY ANALYSIS

9.1 Load savings shapes

The goal of the load savings shapes analysis is to produce weather-normalized, wave-specific load savings shapes. Accounting for the unique nature of HER waves across geographies, populations and tenure is essential for HER program load savings shapes. In addition, these load shapes make it possible to understand savings across a range of weather condition including but not limited to typical weather conditions.

The site-level regression models that underpin this approach are based on annual 8,760 hourly load data used to generate unique hourly estimates of consumption change for each customer (treatment and control). The site-level model coefficients are combined with typical meteorological year (TMY) temperatures, and their associated cooling and heating degrees, to generate the hourly load that reflects TMY conditions in both pre and post HER program periods. The estimated hourly difference-in-difference estimates using this approach have substantial noise, but this limitation is overcome by using average hourly loads rather than annual 8,760 individual hour loads.

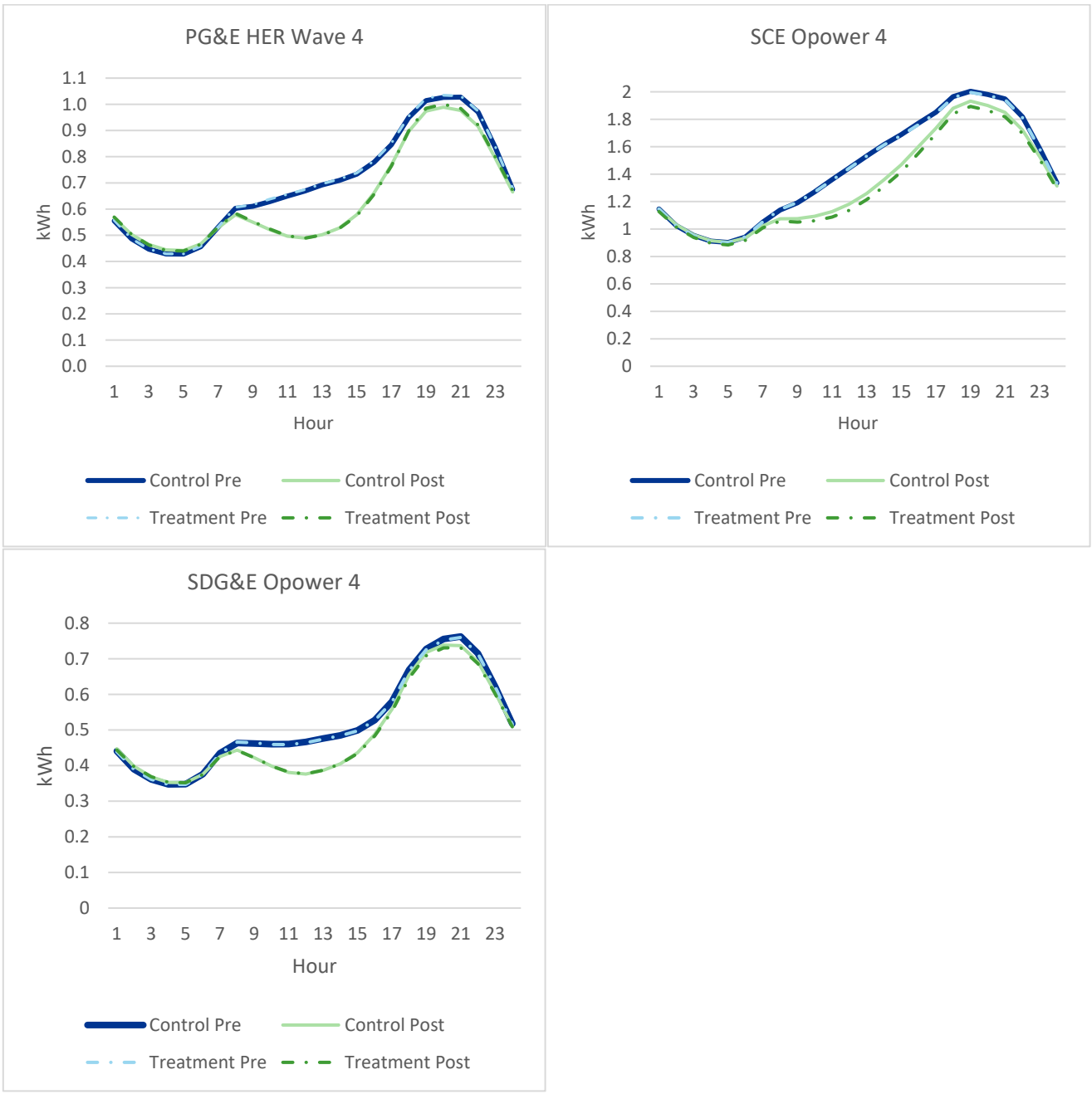
9.1.1 Hourly load shapes

The estimated average hourly load shapes across all treatment and control customers by program period reveal the substantial change in hourly load shape that has taken place over time. Figure 9-1 presents the findings from each of the IOUs. The pre-period shapes for each group are almost indistinguishable and appear in blue on the graph. The 2018 shapes are also hard to distinguish and are shown in green. The dashed lines represent treatment. The different shapes indicate the notable change in both treatment and control customers' hourly load shape from 2014 to 2018. It is noteworthy that treatment and control customer loadshapes in both periods have highly similar load shapes indicating the RCT design and, in the post period, the modest savings effects of HER.

The 2018, (post-period) load shapes indicate a substantial dip in mid-day supplied energy consumption for all three IOUs, a telltale sign of on-site solar production. This dip is apparent for both treatment and control households and is present in approximately equal proportions for the two groups. The striking 2018 departure from the 2014 energy load shapes reveals the substantial inroad on-site solar production has made over the time period under study.

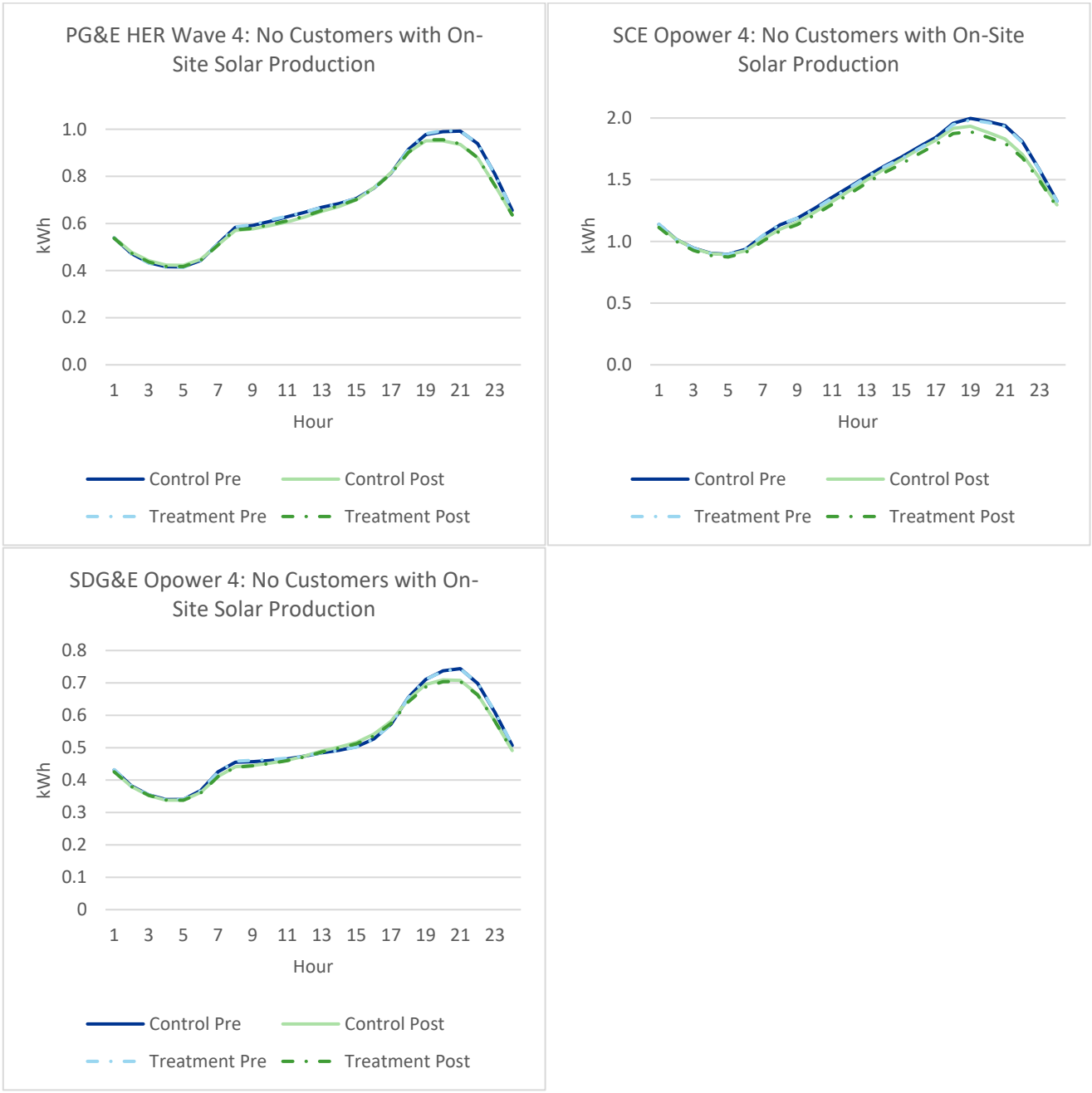
The average hourly load shapes of the pre and post periods also indicate a notable reduction in average hourly energy consumption over all hours. There is a clear separation between the energy consumption of both treatment and control customers in the pre and post periods. While the difference between pre and post period hourly load is apparent, the difference in consumption between the treatment and control groups is less apparent. Similar to what energy savings estimates from the HER programs indicate, the hourly load savings shapes indicate a thin separation in energy consumption between the treatment and control groups in the post period compared to the pre. The difference-in-difference implied by each panel captures this. The load savings shape will be examined in more detail in the next section.

Figure 9-1. Average hourly load and load savings shapes by IOU



We also examine the load shape for these customers after removing data from those on-site solar generation. While the hourly load shapes over time become more similar in the pre and post periods, the reduction in energy consumption in the peak early evening hours is apparent across all IOUs. The downward trend could reflect a general improvement in household energy efficiency or behavior change across both treatment and control groups. Like the average hourly load shapes for all customers, the figures without solar customers for all three IOUs are similar and indicate a similar downward shift in peak hour energy consumption in the post period. Figure 9-2 provides the hourly load shapes for the chosen HER waves of each IOU without solar customers.

Figure 9-2. Average hourly load and load savings shapes without solar customers by IOU

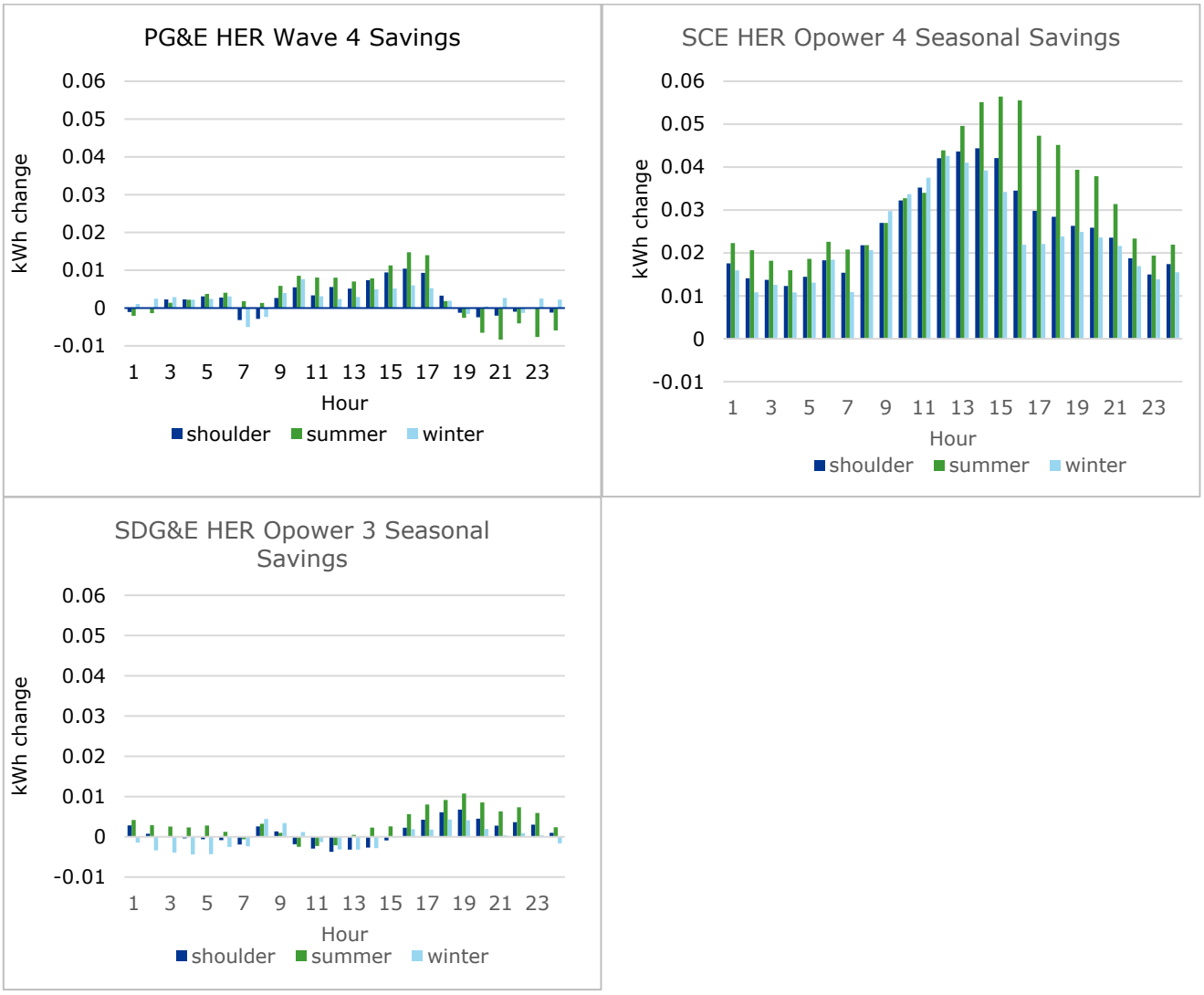


9.1.2 Savings by hour

Figure 9-3 presents average hourly load savings shapes by season and IOU for HER treatment customers in the indicated waves. Average hourly load savings shapes have strong seasonal elements with the highest savings occurring in the summer months. The savings for SCE's selected HER wave are substantial compared to the other IOUs. They occur at all hours of the day during all seasons of the year, with the highest savings being for the part of middle of the day. Savings that are in evidence for SDG&E occur during the early evening peak demand period for all seasons and in the early morning hours during the summer. PG&E's lower HER wave load savings shape indicates that seasonal average hourly load savings are

concentrated in the middle of the day across all seasons. The heterogeneity in magnitude and load savings shape across the IOUs may reflect the different mix of recipients that are in each cohort and the different weather conditions that they face. It is also possible that the relatively modest randomized subsets on which these shapes are based are also responsible for the variation.

Figure 9-3. Average hourly load shapes by season and IOU



9.2 Savings persistence

DNV GL studied the persistence of savings among homes that received HER treatment, but which changed ownership at some point during the post period. The study was based on data from PG&E's Wave 3, which was launched in July 2013. This wave included about 300,000 initial participants and targeted high usage dual fuel homes. It is currently in its fifth full year and provides the kind of data, with sufficiently long history and a representative HER customer base that makes it suitable for this study. Table 9-1 provides the counts of households used in the study.

Table 9-1. Premise counts in persistence study

Group	Initial participating counts	Current sample counts	Current mover counts	Current active counts	Total movers	Movers not in current sample	% movers in current sample
Control	75,020	55,223	10,555	44,668	30,352	19,797	35%
Treatment	224,993	166,016	31,851	134,165	90,828	58,977	35%

As the table indicates, the number of total premises used in the study is less than the number of full wave participants because the anonymization of customer identifiers and an incomplete mapping of anonymous to real identifiers prevented a complete identification of movers. About 35% of movers are in the sample and are present in equal proportion in treatment and control groups, allowing for unbiased inference. The only expected effect of this data issue is that these preliminary results will be lower precision than results that include all movers.

Table 9-2 shows that the percentages of new movers in treatment and control groups included in the sample. It indicates increasingly lower additions of new movers over time. The year 2016 had the highest year-over-year percent of new movers at 98%, while 2018 only saw 20% new movers.

Table 9-2. Number of control and treatment group movers by year

Year	Count of control movers	Count of treat movers	Percent new movers (control)	Percent new movers (control)
2015	109	330	100%	100%
2016	4,615	13,503	98%	98%
2017	8,333	24,664	45%	45%
2018	10,526	31,751	21%	22%

9.2.1 Overall savings for HER movers

We examine electricity use trends at homes of the chosen HER wave to explore the effect of attrition on HER savings. Figure 9-4 provides average monthly kWh for the set of active and mover HER participants across time. There are several things to note:

- Prior to the start of the HER program in July 2013, average daily kWh in each month was fairly balanced between treatment and control households; the dark and light blue lines that represent the two groups trace near identical energy use
- After HER treatment began, the separation between treatment and control lines is apparent with the light blue line representing control group customers discernibly above the dark blue line representing treatment group customers
- In the current sample, movers were first observed in late 2015 and are marked by the aqua and green lines
- The lines representing movers are below those of non-movers because some homes vacated by participants remain unoccupied for a period of time
- These lines also clearly indicate that the energy use of homes occupied by households that received HER treatment are lower than control group movers; in general, the aqua line that represent such homes is lower than the green line of control group movers

Figure 9-4. Average daily kWh by month, pre and post HER and post move

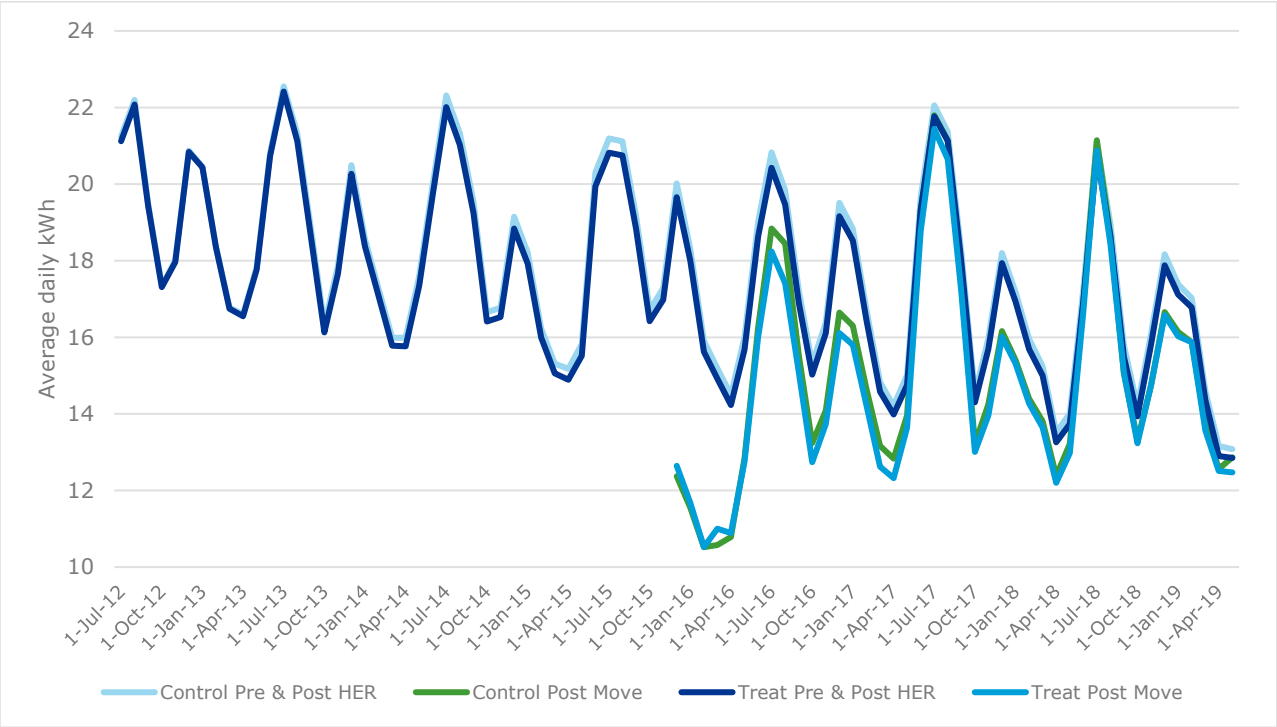


Table 9-3 provides a preliminary indication of the savings found at homes previously occupied by HER treatment households. The values here are simple population means of average daily kWh at the different treatment stages. HER savings indicated by the difference in difference of pre and post average daily kWh values show a savings of 0.22 kWh per day. Post move, all previously treated homes still save 0.18 kWh per day, which is about 80% of the savings prior to the move.

Table 9-3. Average daily use by customer group and period

	Group	Treatment Stages	Average daily kWh	Control - Treat difference types		Differences
A	Control	Pre HER	19.18			
B	Treat	Pre HER	19.13	Pre	A-B	0.06
C	Control	Post HER	17.65			
D	Treat	Post HER	17.37	Pre-Post HER	(C-D)-(A-B)	-0.22
E	Control	Post Move	15.52			
F	Treat	Post Move	15.29	Pre-Post Move	(E-F)-(A-B)	-0.18

A more formal approach to investigate the persistence of savings in previously treated HER homes and its change over time uses the panel fixed effects model presented in section 3.7. The model controls for premise level and time specific effects, which account for premise level characteristics that are time invariant and time specific effects that capture general trends in energy use. It also accounts for general post-move conditions, such as declines in energy use while homes change occupancy. Most importantly, the model is specified to provide estimates of average daily kWh changes due to HER treatment for both active and previously treated HER homes.

Table 9-4 provides these estimates across all years included in the study. It indicates a 0.22 kWh per household reduction in average daily energy use due to HER treatment and 0.12 kWh less energy use among homes previously occupied by HER treatment households. The estimated HER savings translates to a 1.1% reduction from baseline use (80 kWh annual) while persistent energy savings in previously treated homes is estimated to be 0.6% of baseline consumption (45 kWh annually). The model indicates a notable persistence of HER savings amounting to 55% HER treatment effects.

Table 9-4. Average daily kWh HER program savings for active recipients and movers

Estimates	All years	Movers through 2016	Movers through 2017	Movers through 2018	Movers through early 2019
BT = HER Treatment effect	-0.22	-0.27	-0.22	-0.25	-0.21
BM = Post move condition	-1.53	-2.70	-1.56	-1.21	-1.18
BMT = HER movers savings	-0.12	-0.19	-0.18	-0.01	0.03

9.2.2 Savings trend for HER movers

Table 9-4 also provides savings estimates by movers across the years. It reflects the change in the persistence of HER savings as the mix of movers changes over time (Table 9-2). The effect of savings persistence appears to decline and reflects the decreasing share of new movers. In 2016, almost all moves had occurred recently, and the estimated persistence is 0.19 kWh. By 2018, there are only 20% new movers and the estimated persistence for all movers up to that time is 0.01 kWh.

One possible explanation for the decline in persistence is a closing gap in energy efficiency between previously treated HER homes and those that were in the control group. In addition, after 12 months the newly-occupied homes become eligible for subsequent HER waves and could have been enrolled in later HER program waves. Thus, within a couple of years of the move, the prior control group house may be a transformed treatment group house, eroding the difference between the prior mover groups. It is also possible that there is heterogeneity in persistence across different cohorts of movers.

9.2.3 Implications

These preliminary results replicate academic findings on this topic and provide evidence of the persistence of HER savings in previously treated homes in CA. This persistence points to physical investments made in response to HER that remain at the home when there is occupancy change, such as energy efficient equipment and related home features. These are real savings that can be conclusively attributed to the original HER treatment.

Further research on this subject can address a number of important questions related to this finding. It will be possible to quantify how these savings attached to installation of energy efficiency measures differ from wave to wave and PA to PA. Furthermore, it will be possible to track participation in subsequent HER waves and understand whether this is a cause of the apparent erosion of these durable savings over time. In combination, this research should uncover substantial amounts of previously unidentified savings while leading to a better understanding of the potential of future HER waves.

10 CONCLUSIONS AND RECOMMENDATIONS

As in prior years, HER continues to be a residential energy savings workhorse with verified energy and demand savings ensuring residential energy efficiency programs deliver sizable and durable energy savings. Program savings in 2018 exceed those estimated in 2017 due to continued savings per household and the addition of new waves. Programs continue to maintain sound RCT design ensuring that measured savings are not only significant but also reliable.

The sound experimental design of the HER program provides accurate and highly precise information on the savings that can be attributed to the HER program.

However, the increasing trend of solar use raises some concern about the accuracy with which HER program savings are measured. Billing data generally provide household energy consumption that is net of household self-generation. If the HER program drives either greater adoption of solar or solar panels that are substantially differently sized than those installed by control group homes, the estimated program savings will be biased.

DNV GL recommends that greater attention be paid to the interaction of on-site solar adoption with the HER programs. It is a reasonable hypothesis that HER reports could affect the subsequent decision to adopt PV or the size of the installation. If this is the case, then HER savings estimates will no longer solely reflect HER savings. The only complete solution to this challenge is the metering of residential PV which will have multiple additional benefits, but which will represent a massive undertaking.

In addition to energy savings, HER program participant load shapes indicate significant changes in average hourly energy consumption among report recipients. Both treatment and control customers' load shapes in the program year evaluated (2018) compared to pre-period conditions, which happened a number of years earlier for the waves used for this investigation, indicate average mid-day energy consumption declines that are clear and discernible. The increasing presence of on-site solar production contributes to this dip and has led to characteristic duck curve load shapes. In addition, program participants' average hourly load estimates, that have been weather normalized to control for the effect of weather changes on energy consumption, reflect another notable feature: lower energy consumption in 2018 compared to the pre-period.

The HER program has contributed to this trend by enhancing the decline in average hourly energy consumption, in either all hours of the day or during the early morning or early evening peak demand hours. These declines have a seasonal component, where average hourly load reductions are even higher during the hot summer and, in some cases, the cool winter seasons.

The HER load shapes are exploratory and offer a way to develop new program load savings shape for use in cost effectiveness and other avoided cost calculations. DNV GL recommends continued refinement of this analysis in future evaluation cycles.

11 APPENDICES

11.1 Appendix A: Gross and Net Lifecycle Savings

Gross Lifecycle Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	133,100	125,615	0.94	0.0%	0.94
PGE	**Total**	**133,100**	**125,615**	**0.94**	**0.0%**	**0.94**
SCE	HER - Wave 2	4,863	3,300	0.68	0.0%	0.68
SCE	HER - Wave 3	14,835	15,147	1.02	0.0%	1.02
SCE	HER - Wave 4	29,858	32,716	1.10	0.0%	1.10
SCE	HER - Wave 5	55,273	61,965	1.12	0.0%	1.12
SCE	HER - Wave 6	14,186	13,040	0.92	0.0%	0.92
SCE	HER - Wave 7	1,366	1,728	1.26	0.0%	1.26
SCE	**Total**	**120,381**	**127,895**	**1.06**	**0.0%**	**1.06**
SCG	HER	0	0			
SCG	**Total**	**0**	**0**			
SDGE	HER	37,561	49,749	1.32	0.0%	1.32
SDGE	**Total**	**37,561**	**49,749**	**1.32**	**0.0%**	**1.32**
	Statewide	***291,042***	***303,260***	***1.04***	***0.0%***	***1.04***

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	HER	139,755	131,896	0.94	100.0%	1.05	1.05		
PGE	**Total**	**139,755**	**131,896**	**0.94**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	5,106	3,465	0.68	100.0%	1.05	1.05		
SCE	HER - Wave 3	15,577	15,904	1.02	100.0%	1.05	1.05		
SCE	HER - Wave 4	31,350	34,352	1.10	100.0%	1.05	1.05		
SCE	HER - Wave 5	58,036	65,063	1.12	100.0%	1.05	1.05		
SCE	HER - Wave 6	14,896	13,692	0.92	100.0%	1.05	1.05		
SCE	HER - Wave 7	1,435	1,814	1.26	100.0%	1.05	1.05		
SCE	**Total**	**126,400**	**134,290**	**1.06**	**100.0%**	**1.05**	**1.05**		
SCG	HER	0	0						
SCG	**Total**	**0**	**0**						
SDGE	HER	39,439	52,237	1.32	100.0%	1.05	1.05		
SDGE	**Total**	**39,439**	**52,237**	**1.32**	**100.0%**	**1.05**	**1.05**		
	Statewide	***305,594***	***318,423***	***1.04***	***100.0%***	***1.05***	***1.05***		

Gross Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	24.0	30.0	1.25	0.0%	1.25
PGE	**Total**	**24.0**	**30.0**	**1.25**	**0.0%**	**1.25**
SCE	HER - Wave 2	1.0	1.6	1.71	0.0%	1.71
SCE	HER - Wave 3	1.8	3.8	2.06	0.0%	2.06
SCE	HER - Wave 4	7.0	5.3	0.76	0.0%	0.76
SCE	HER - Wave 5	16.9	11.1	0.66	0.0%	0.66
SCE	HER - Wave 6	8.9	6.8	0.76	0.0%	0.76
SCE	HER - Wave 7	0.0	0.0			
SCE	**Total**	**35.6**	**28.6**	**0.80**	**0.0%**	**0.80**
SCG	HER	0.0	0.0			
SCG	**Total**	**0.0**	**0.0**			
SDGE	HER	50.6	7.9	0.16	0.0%	0.16
SDGE	**Total**	**50.6**	**7.9**	**0.16**	**0.0%**	**0.16**
	Statewide	***110.2***	***66.5***	***0.60***	***0.0%***	***0.60***

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	HER	25.2	31.5	1.25	100.0%	1.05	1.05		
PGE	**Total**	**25.2**	**31.5**	**1.25**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	1.0	1.7	1.71	100.0%	1.05	1.05		
SCE	HER - Wave 3	1.9	3.9	2.06	100.0%	1.05	1.05		
SCE	HER - Wave 4	7.3	5.6	0.76	100.0%	1.05	1.05		
SCE	HER - Wave 5	17.8	11.7	0.66	100.0%	1.05	1.05		
SCE	HER - Wave 6	9.4	7.1	0.76	100.0%	1.05	1.05		
SCE	HER - Wave 7	0.0	0.0						
SCE	**Total**	**37.4**	**30.1**	**0.80**	**100.0%**	**1.05**	**1.05**		
SCG	HER	0.0	0.0						
SCG	**Total**	**0.0**	**0.0**						
SDGE	HER	53.2	8.3	0.16	100.0%	1.05	1.05		
SDGE	**Total**	**53.2**	**8.3**	**0.16**	**100.0%**	**1.05**	**1.05**		
	Statewide	***115.7***	***69.8***	***0.60***	***100.0%***	***1.05***	***1.05***		

Gross Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	4,900	4,770	0.97	0.0%	0.97
PGE	**Total**	**4,900**	**4,770**	**0.97**	**0.0%**	**0.97**
SCE	HER - Wave 2	0	0			
SCE	HER - Wave 3	0	0			
SCE	HER - Wave 4	0	0			
SCE	HER - Wave 5	0	0			
SCE	HER - Wave 6	0	0			
SCE	HER - Wave 7	0	0			
SCE	**Total**	**0**	**0**			
SCG	HER	4,754	4,712	0.99	0.0%	0.99
SCG	**Total**	**4,754**	**4,712**	**0.99**	**0.0%**	**0.99**
SDGE	HER	913	1,139	1.25	0.0%	1.25
SDGE	**Total**	**913**	**1,139**	**1.25**	**0.0%**	**1.25**
	Statewide	***10,567***	***10,621***	***1.01***	***0.0%***	***1.01***

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	HER	5,145	5,008	0.97	100.0%	1.05	1.05		
PGE	**Total**	**5,145**	**5,008**	**0.97**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	0	0						
SCE	HER - Wave 3	0	0						
SCE	HER - Wave 4	0	0						
SCE	HER - Wave 5	0	0						
SCE	HER - Wave 6	0	0						
SCE	HER - Wave 7	0	0						
SCE	**Total**	**0**	**0**						
SCG	HER	4,992	4,948	0.99	100.0%	1.05	1.05		
SCG	**Total**	**4,992**	**4,948**	**0.99**	**100.0%**	**1.05**	**1.05**		
SDGE	HER	959	1,196	1.25	100.0%	1.05	1.05		
SDGE	**Total**	**959**	**1,196**	**1.25**	**100.0%**	**1.05**	**1.05**		
	Statewide	***11,095***	***11,152***	***1.01***	***100.0%***	***1.05***	***1.05***		

Gross First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	133,100	125,615	0.94	0.0%	0.94
PGE	**Total**	**133,100**	**125,615**	**0.94**	**0.0%**	**0.94**
SCE	HER - Wave 2	4,863	3,300	0.68	0.0%	0.68
SCE	HER - Wave 3	14,835	15,147	1.02	0.0%	1.02
SCE	HER - Wave 4	29,858	32,716	1.10	0.0%	1.10
SCE	HER - Wave 5	55,273	61,965	1.12	0.0%	1.12
SCE	HER - Wave 6	14,186	13,040	0.92	0.0%	0.92
SCE	HER - Wave 7	1,366	1,728	1.26	0.0%	1.26
SCE	**Total**	**120,381**	**127,895**	**1.06**	**0.0%**	**1.06**
SCG	HER	0	0			
SCG	**Total**	**0**	**0**			
SDGE	HER	37,561	49,749	1.32	0.0%	1.32
SDGE	**Total**	**37,561**	**49,749**	**1.32**	**0.0%**	**1.32**
	Statewide	***291,042***	***303,260***	***1.04***	***0.0%***	***1.04***

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	HER	139,755	131,896	0.94	100.0%	1.05	1.05		
PGE	**Total**	**139,755**	**131,896**	**0.94**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	5,106	3,465	0.68	100.0%	1.05	1.05		
SCE	HER - Wave 3	15,577	15,904	1.02	100.0%	1.05	1.05		
SCE	HER - Wave 4	31,350	34,352	1.10	100.0%	1.05	1.05		
SCE	HER - Wave 5	58,036	65,063	1.12	100.0%	1.05	1.05		
SCE	HER - Wave 6	14,896	13,692	0.92	100.0%	1.05	1.05		
SCE	HER - Wave 7	1,435	1,814	1.26	100.0%	1.05	1.05		
SCE	**Total**	**126,400**	**134,290**	**1.06**	**100.0%**	**1.05**	**1.05**		
SCG	HER	0	0						
SCG	**Total**	**0**	**0**						
SDGE	HER	39,439	52,237	1.32	100.0%	1.05	1.05		
SDGE	**Total**	**39,439**	**52,237**	**1.32**	**100.0%**	**1.05**	**1.05**		
	Statewide	***305,594***	***318,423***	***1.04***	***100.0%***	***1.05***	***1.05***		

Gross First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	24.0	30.0	1.25	0.0%	1.25
PGE	**Total**	**24.0**	**30.0**	**1.25**	**0.0%**	**1.25**
SCE	HER - Wave 2	1.0	1.6	1.71	0.0%	1.71
SCE	HER - Wave 3	1.8	3.8	2.06	0.0%	2.06
SCE	HER - Wave 4	7.0	5.3	0.76	0.0%	0.76
SCE	HER - Wave 5	16.9	11.1	0.66	0.0%	0.66
SCE	HER - Wave 6	8.9	6.8	0.76	0.0%	0.76
SCE	HER - Wave 7	0.0	0.0			
SCE	**Total**	**35.6**	**28.6**	**0.80**	**0.0%**	**0.80**
SCG	HER	0.0	0.0			
SCG	**Total**	**0.0**	**0.0**			
SDGE	HER	50.6	7.9	0.16	0.0%	0.16
SDGE	**Total**	**50.6**	**7.9**	**0.16**	**0.0%**	**0.16**
	Statewide	***110.2***	***66.5***	***0.60***	***0.0%***	***0.60***

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	HER	25.2	31.5	1.25	100.0%	1.05	1.05		
PGE	**Total**	**25.2**	**31.5**	**1.25**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	1.0	1.7	1.71	100.0%	1.05	1.05		
SCE	HER - Wave 3	1.9	3.9	2.06	100.0%	1.05	1.05		
SCE	HER - Wave 4	7.3	5.6	0.76	100.0%	1.05	1.05		
SCE	HER - Wave 5	17.8	11.7	0.66	100.0%	1.05	1.05		
SCE	HER - Wave 6	9.4	7.1	0.76	100.0%	1.05	1.05		
SCE	HER - Wave 7	0.0	0.0						
SCE	**Total**	**37.4**	**30.1**	**0.80**	**100.0%**	**1.05**	**1.05**		
SCG	HER	0.0	0.0						
SCG	**Total**	**0.0**	**0.0**						
SDGE	HER	53.2	8.3	0.16	100.0%	1.05	1.05		
SDGE	**Total**	**53.2**	**8.3**	**0.16**	**100.0%**	**1.05**	**1.05**		
	Statewide	***115.7***	***69.8***	***0.60***	***100.0%***	***1.05***	***1.05***		

Gross First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HER	4,900	4,770	0.97	0.0%	0.97
PGE	**Total**	**4,900**	**4,770**	**0.97**	**0.0%**	**0.97**
SCE	HER - Wave 2	0	0			
SCE	HER - Wave 3	0	0			
SCE	HER - Wave 4	0	0			
SCE	HER - Wave 5	0	0			
SCE	HER - Wave 6	0	0			
SCE	HER - Wave 7	0	0			
SCE	**Total**	**0**	**0**			
SCG	HER	4,754	4,712	0.99	0.0%	0.99
SCG	**Total**	**4,754**	**4,712**	**0.99**	**0.0%**	**0.99**
SDGE	HER	913	1,139	1.25	0.0%	1.25
SDGE	**Total**	**913**	**1,139**	**1.25**	**0.0%**	**1.25**
	Statewide	***10,567***	***10,621***	***1.01***	***0.0%***	***1.01***

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	HER	5,145	5,008	0.97	100.0%	1.05	1.05		
PGE	**Total**	**5,145**	**5,008**	**0.97**	**100.0%**	**1.05**	**1.05**		
SCE	HER - Wave 2	0	0						
SCE	HER - Wave 3	0	0						
SCE	HER - Wave 4	0	0						
SCE	HER - Wave 5	0	0						
SCE	HER - Wave 6	0	0						
SCE	HER - Wave 7	0	0						
SCE	**Total**	**0**	**0**						
SCG	HER	4,992	4,948	0.99	100.0%	1.05	1.05		
SCG	**Total**	**4,992**	**4,948**	**0.99**	**100.0%**	**1.05**	**1.05**		
SDGE	HER	959	1,196	1.25	100.0%	1.05	1.05		
SDGE	**Total**	**959**	**1,196**	**1.25**	**100.0%**	**1.05**	**1.05**		
	Statewide	***11,095***	***11,152***	***1.01***	***100.0%***	***1.05***	***1.05***		

11.2 Appendix B: Per Unit (Quantity) Gross and Net Energy Savings

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	HER	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 2	0	0.0%	0.0%	1.0	824,910.8	824,910.8	824,910.8
SCE	HER - Wave 3	0	0.0%	0.0%	1.0	3,786,671.3	3,786,671.3	3,786,671.3
SCE	HER - Wave 4	0	0.0%	0.0%	1.0	8,179,068.3	8,179,068.3	8,179,068.3
SCE	HER - Wave 5	0	0.0%	0.0%	1.0	15,491,197.3	15,491,197.3	15,491,197.3
SCE	HER - Wave 6	0	0.0%	0.0%	1.0	3,260,084.0	3,260,084.0	3,260,084.0
SCE	HER - Wave 7	0	0.0%	0.0%	1.0	863,813.0	863,813.0	863,813.0
SCG	HER	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SDGE	HER	0	0.0%	0.0%	1.0	4,145,772.1	4,145,772.1	4,145,772.1

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	HER	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 2	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 3	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 4	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 5	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 6	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCE	HER - Wave 7	0	0.0%	0.0%	1.0	0.0	0.0	0.0
SCG	HER	0	0.0%	0.0%	1.0	2,356,149.0	2,356,149.0	2,356,149.0
SDGE	HER	0	0.0%	0.0%	1.0	94,905.6	94,905.6	94,905.6

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	HER	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 2	1	0.0%		1.0	866,156.3	866,156.3	866,156.3
SCE	HER - Wave 3	1	0.0%		1.0	3,976,004.8	3,976,004.8	3,976,004.8
SCE	HER - Wave 4	1	0.0%		1.0	8,588,021.7	8,588,021.7	8,588,021.7
SCE	HER - Wave 5	1	0.0%		1.0	16,265,757.1	16,265,757.1	16,265,757.1
SCE	HER - Wave 6	1	0.0%		1.0	3,423,088.2	3,423,088.2	3,423,088.2
SCE	HER - Wave 7	1	0.0%		1.0	907,003.7	907,003.7	907,003.7
SCG	HER	1	0.0%		1.0	0.0	0.0	0.0
SDGE	HER	1	0.0%		1.0	4,353,060.7	4,353,060.7	4,353,060.7

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	HER	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 2	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 3	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 4	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 5	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 6	1	0.0%		1.0	0.0	0.0	0.0
SCE	HER - Wave 7	1	0.0%		1.0	0.0	0.0	0.0
SCG	HER	1	0.0%		1.0	2,473,956.5	2,473,956.5	2,473,956.5
SDGE	HER	1	0.0%		1.0	99,650.8	99,650.8	99,650.8

11.3 Appendix C: IESR–Recommendations resulting from the evaluation research

Study ID	Study Type	Study Title	CPUC Study Manager
Group A Residential Sector	Impact Evaluation	Impact Evaluation Report of Home Energy Reports (HER)	Peter Franzese

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
1	HER	HER continues to be a residential energy savings workhorse with verified energy and demand savings ensuring residential energy efficiency programs deliver sizable and durable energy savings.	Sections 5 - 7	The sound experimental design of the HER program provides accurate and highly precise information on the savings that can be attributed to the HER program.	All PAs	
2	HER	The increasing trend of solar use raises some concern about the accuracy with which HER program savings are measured.	Section 8	DNV GL recommends that greater attention be paid to the interaction of on-site solar adoption with the HER programs. It is a reasonable hypothesis that HER reports could affect the subsequent decision to adopt PV or the size of the installation. If this is the case, then HER savings estimates will no longer solely reflect HER savings. The only complete solution to this challenge is the metering of residential PV which will have multiple additional benefits, but which will represent a massive undertaking.	All PAs, CPUC ED EM&V	
3	HER	Unlike current assumption, there is considerable variability in hourly HER program savings by time of day and PA. Since hourly HER program savings have variation by wave, it appears that there is no singular HER load shape that can be applied to all waves	Section 9	DNV GL recommends continued refinement of the exploratory load savings shape analysis in future evaluation cycles. The HER load shapes built this way offer a way to develop new program load savings shapes for use in cost effectiveness and other avoided cost calculations.	All PAs, CPUC ED	

11.4 Appendix D: Total savings at a glance

The figures in Appendix D present total HER program energy and peak demand savings by PA. Negative joint savings values denote the tracked downstream and untracked upstream savings that other programs claim; hence, that DNV GL removes from unadjusted program savings to obtain the total (adjusted) HER program savings.

Figure 11-1. PG&E total electric savings for the 2018 HER program

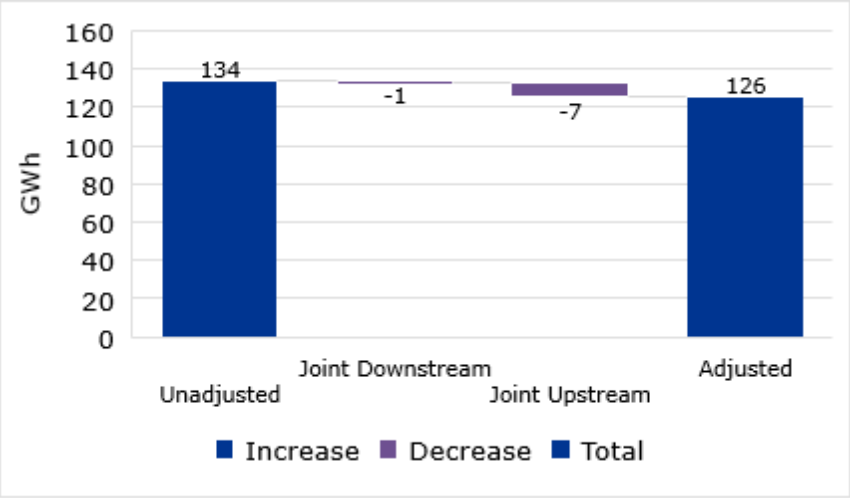


Figure 11-2. PG&E total gas savings for the 2018 HER program

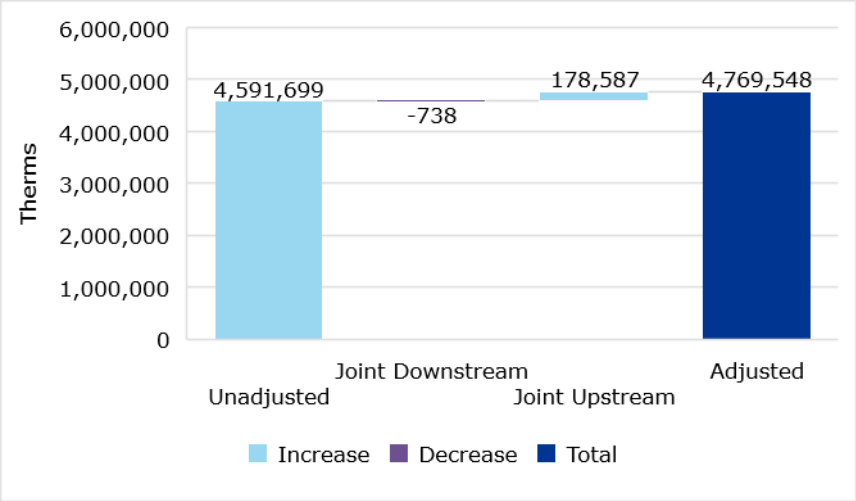


Figure 11-3. PG&E total peak demand savings for the 2018 HER program

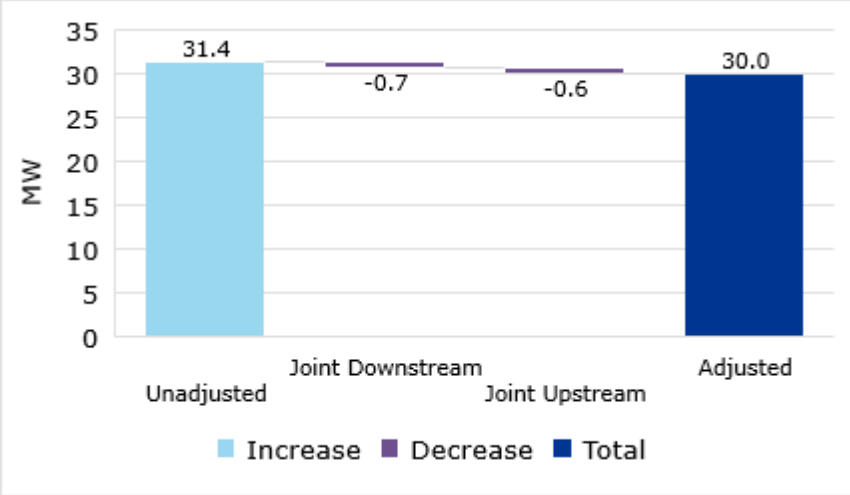


Figure 11-4. SDG&E total electric savings for the 2018 HER program

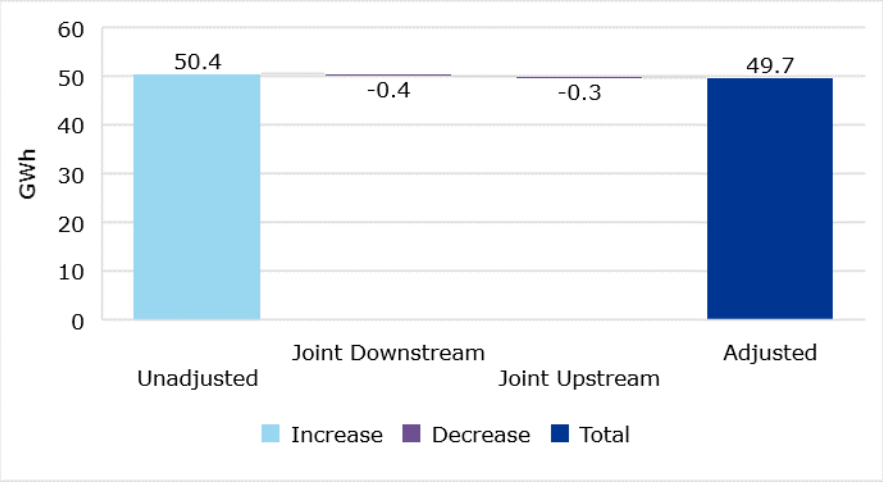


Figure 11-5. SDG&E total gas savings for the 2018 HER program

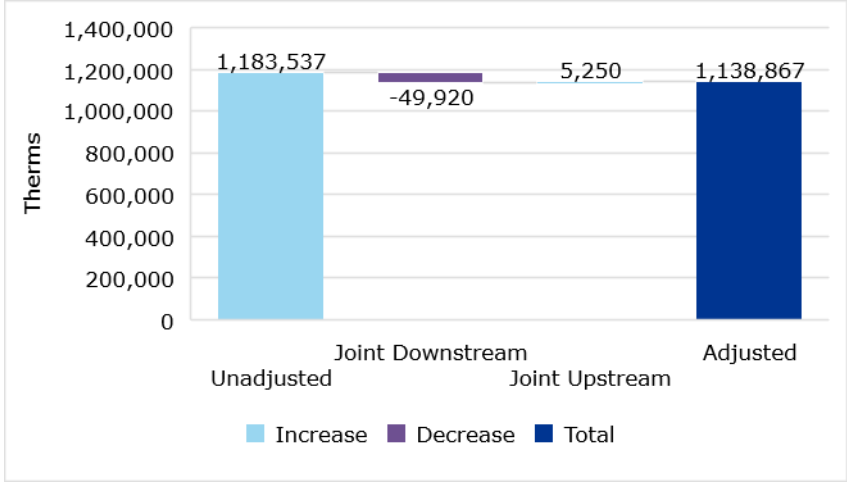


Figure 11-6. SDG&E total peak demand savings for the 2018 HER program

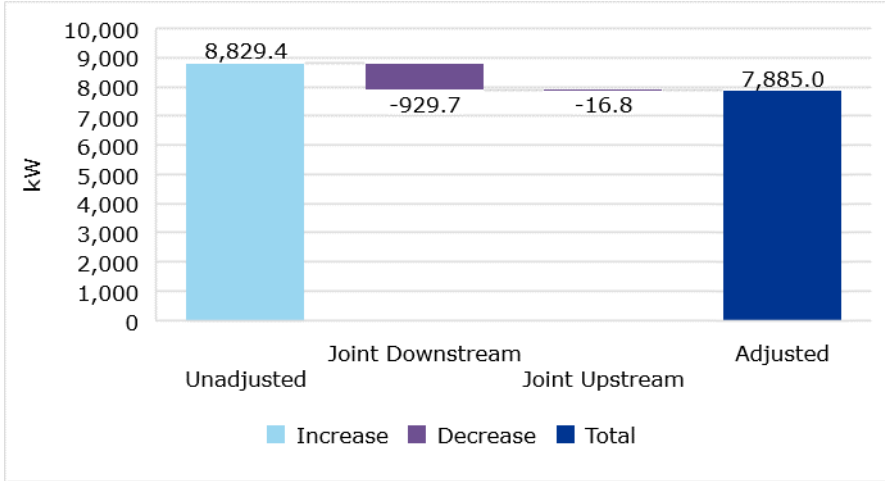


Figure 11-7. SCE total electric savings for the 2018 HER program

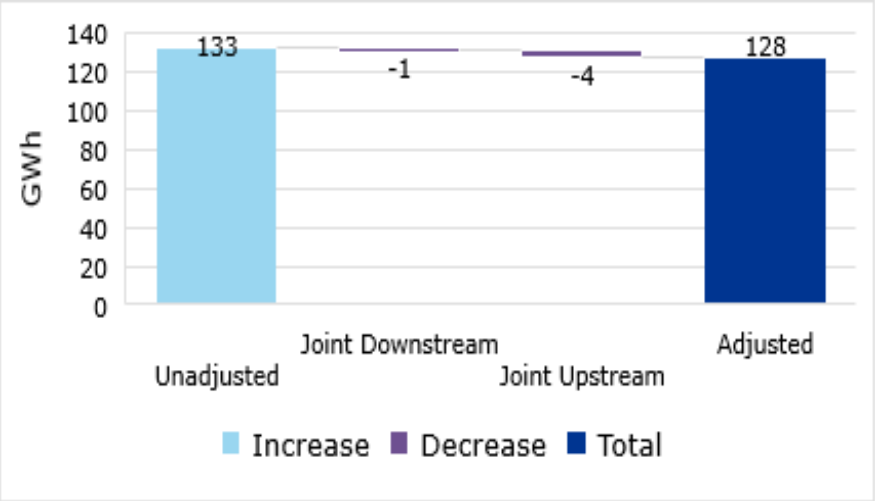


Figure 11-8. SCE total peak demand savings for the 2018 HER program

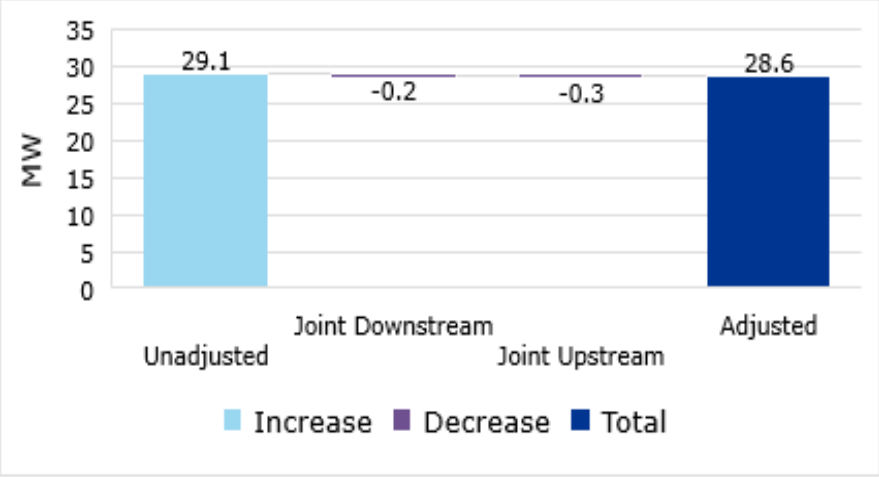
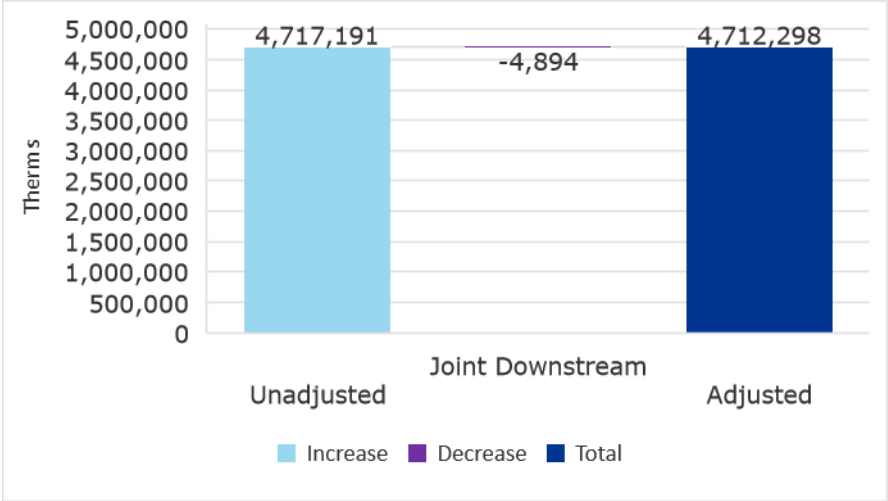


Figure 11-9. SCG total gas savings for the 2018 HER program



11.5 Appendix E: HER program waves and population counts

The tables in Appendix E present total HER customer counts by wave and PA. Table 11-1. presents these counts for PG&E's HER customers. PG&E treatment and control customers moved out at about the same rate in 2018; however, waves launched before 2014 experienced lower attrition rates (5%-7%) than later waves (7%-13%). Wave 7 experienced the highest attrition in 2018.

Table 11-1. PG&E HER customer attrition

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Beta		**Wave 2 area 7**	
Original sample	59,994	59,994	80,051	50,071
Attrition (move-outs)	21,070	20,852	25,741	16,193
Active customers, Jan. 2018	38,924	39,142	54,310	33,878
Active customers, Dec. 2018	37,086	37,227	51,545	32,130
	Gamma standard		**Wave 2 non-area 7**	
Original sample	72,287	72,292	305,284	47,708
Attrition (move-outs)	27,894	27,944	93,661	14,664
Active customers, Jan. 2018	44,393	44,348	211,623	33,044
Active customers, Dec. 2018	42,124	42,140	200,947	31,346
	Gamma reduced		**Wave 3**	
Original sample	72,286	72,292	224,996	75,020
Attrition (move-outs)	27,847	27,944	83,869	28,178
Active customers, Jan. 2018	44,439	44,348	141,127	46,842
Active customers, Dec. 2018	42,184	42,140	131,969	43,987
	Gamma electric only		**Wave 4**	
Original sample	44,985	44,992	200,000	75,000
Attrition (move-outs)	23,703	23,745	81,362	30,420
Active customers, Jan. 2018	21,282	21,247	118,638	44,580
Active customers, Dec. 2018	19,712	19,715	108,881	40,892
	Wave 1 dual fuel		**Wave 5**	
Original sample	360,200	89,993	210,000	50,200
Attrition (move-outs)	128,784	31,961	69,678	16,767
Active customers, Jan. 2018	231,416	58,032	140,322	33,433
Active customers, Dec. 2018	219,260	54,917	128,978	30,750
	Wave 1 electric only		**Wave 6**	
Original sample	39,787	9,999	312,000	50,000
Attrition (move-outs)	18,774	4,709	104,304	16,770
Active customers, Jan. 2018	21,013	5,290	207,696	33,230
Active customers, Dec. 2018	19,519	4,932	185,014	29,566

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 7		**Wave 9**	
Original sample	157,496	39,997	105,000	20,000
Attrition (move-outs)	22,847	5,834	3,344	615
Active customers, Jan. 2018	134,649	34,163	101,656*	19,385
Active customers, Dec. 2018	117,798	29,965	94,911	18,056
	Wave 8			
Original sample	143,000	22,000		
Attrition (move-outs)	4,243	658		
Active customers, Jan. 2018	138,757	21,342		
Active customers, Dec. 2018	123,168	18,959		

*PG&E launched Wave 9 in August 2018, so this count represents active customers as of August 2018 instead of January 2018

DNV GL provides SDG&E's customer attrition varies by fuel since these differ significantly. Table 11-2. presents counts of SDG&E's electric HER customers whose attrition was slower than gas customer attrition (Table 11-3). SDG&E's electric treatment and control customers moved out at about the same rate in 2018; however, attrition rates in 2018 vary greatly across waves, ranging from 5% in Opower 1 to 24% in Opower 4 Digital. Later waves tend to experience greater attrition rates than earlier waves.

Table 11-2. SDG&E HER electric program attrition

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 1		**Wave 3 expansion paper**	
Original sample	19,977	19,909	195,670	24,697
Attrition (move-outs)	7,768	7,782	41,561	5,217
Active customers, Jan. 2018	12,209	12,127	154,109	19,480
Active customers, Dec. 2018	11,564	11,483	142,608	18,033
	Wave 2 low-income		**Wave 4 digital**	
Original sample	26,018	7,074	63,178	17,406
Attrition (move-outs)	10,787	2,975	16,408	4,451
Active customers, Jan. 2018	15,231	4,099	46,770	12,955
Active customers, Dec. 2018	13,627	3,696	35,585	9,802
	Wave 2 non-low-income		**Wave 4 paper**	
Original sample	57,175	15,850	48,753	13,893
Attrition (move-outs)	23,388	6,545	6,970	2,032
Active customers, Jan. 2018	33,787	9,305	41,783	11,861
Active customers, Dec. 2018	30,924	8,561	36,002	10,236
	Wave 3 expansion digital		**Wave 5**	
Original sample	265,902	24,687	222,500	35,000
Attrition (move-outs)	96,317	8,990	7,140	1,095
Active customers, Jan. 2018	169,585	15,697	215,360	33,905
Active customers, Dec. 2018	148,909	13,821	174,239	27,500

SDG&E's gas treatment and control customers moved out at about the same rate in 2018; however, attrition rates in 2018 vary greatly across waves, ranging from 5% in Opower 2 Low-Income to 12% in Opower 4 Digital. As with the electric customers, later waves tend to experience greater attrition rates than earlier waves.

Table 11-3. SDG&E HER gas program attrition

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 1		**Wave 3 expansion paper**	
Original sample	19,977	19,909	195,604	24,686
Attrition (move-outs)	10,554	10,544	110,751	14,043
Active customers, Jan. 2018	9,423	9,365	84,853	10,643
Active customers, Dec. 2018	8,486	8,428	74,621	9,385
	Wave 2 low-income		**Wave 4 digital**	
Original sample	26,017	7,074	63,171	17,402
Attrition (move-outs)	15,591	4,227	34,622	9,483
Active customers, Jan. 2018	10,426	2,847	28,549	7,919
Active customers, Dec. 2018	9,249	2,549	22,183	6,149
	Wave 2 non-low-income		**Wave 4 paper**	
Original sample	57,137	15,839	48,739	13,892
Attrition (move-outs)	34,507	9,551	22,845	6,547
Active customers, Jan. 2018	22,630	6,288	25,894	7,345

Active customers, Dec. 2018	20,410	5,683	21,699	6,177
	Wave 3 expansion digital		**Wave 5**	
Original sample	265,836	24,681	222,500	35,000
Attrition (move-outs)	153,213	14,212	85,883	13,261
Active customers, Jan. 2018	112,623	10,469	136,617	21,739
Active customers, Dec. 2018	98,530	9,164	113,172	18,013

Table 11-4. presents these counts for SCE's HER customers. SCE treatment and control customers moved out at about the same rate in 2018; however, attrition rates vary across waves, ranging from 4% in Wave 2 and Wave 7 to 9% in Wave 5. Generally, later waves experienced higher attrition rates than earlier waves.

Table 11-4. SCE HER program attrition

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 2		**Wave 5**	
Original sample	75,000	75,000	602,712	50,104
Attrition (move-outs)	14,528	14,541	63,598	5,246
Active customers, Jan. 2018	60,472	60,459	539,114	44,858
Active customers, Dec. 2018	57,790	57,773	490,368	40,878
	Wave 3		**Wave 6**	
Original sample	164,800	50,315	446,640	44,961
Attrition (move-outs)	27,043	8,403	6,037	645
Active customers, Jan. 2018	137,757	41,912	440,603*	44,316
Active customers, Dec. 2018	130,105	39,585	405,113	40,736
	Wave 4		**Wave 7**	
Original sample	265,650	37,107	357,487	48,671
Attrition (move-outs)	50,842	7,132	14,800	1,978
Active customers, Jan. 2018	214,808	29,975	342,687	46,693
Active customers, Dec. 2018	197,056	27,525	328,898	44,795

*SCE launched Wave 6 in April 2018 and Wave 7 in September 2018, so this count represents active customers as of April and September 2018 instead of January 2018.

Table 11-5. presents SCG's HER program attrition and customer counts in 2018.

Table 11-5. SCG HER program attrition

Sample	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 1		**Wave 5**	
Original sample	182,500	74,202	276,800	50,000
Attrition (move-outs)	36,054	14,102	25,535	4,525
Active customers, Jan. 2018	146,446	60,100	251,265	45,475
Active customers, Dec. 2018	130,418	53,184	225,071	40,883
	Wave 2		**Wave 6a**	
Original sample	124,100	63,194	52,500	46,084
Attrition (move-outs)	18,028	7,997	5,846	4,968
Active customers, Jan. 2018	106,072	55,197	46,654	41,116
Active customers, Dec. 2018	96,545	50,360	42,246	37,270
	Wave 3		**Wave 6b**	
Original sample	41,250	27,500	19,250	13,612
Attrition (move-outs)	7,319	4,682	2,020	1,421
Active customers, Jan. 2018	33,931	22,818	17,230	12,191
Active customers, Dec. 2018	31,028	20,831	15,929	11,295
	Wave 4			
Original sample	164,640	50,000		
Attrition (move-outs)	18,540	5,536		
Active customers, Jan. 2018	146,100	44,464		
Active customers, Dec. 2018	130,380	39,896		

11.6 Appendix F: Data quality

Table 11-16, Table 11-17, Table 11-18, and Table 11-19 present the quality of the data used in the gross savings models. The summaries presented here only pertain to active treatment and control customers in the 2018 program year. Further, the summaries present the quality of data at the customer-fuel level, where a dual-fuel customer could have a data issue for their electric meter but not their gas meter. DNV GL flags an extreme read as daily electric consumption in excess of 100 kWh or daily gas consumption in excess of 10 therms. A household may have zero reads, negative reads, missing reads, and extreme reads, so the percentages may be greater than 100%.

Table 11-6. PG&E data quality summary

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Beta		**Wave 1 electric only**	
Zero reads	194	210	104	29
Negative reads	4,158	4,023	2,252	560
Missing reads	2,166	2,192	22,431	5,634
Extreme reads	1,075	1,191	371	80
No issues	33,832	34,049	165	36
	Gamma standard		**Wave 2 area 7**	
Zero reads	253	310	314	191
Negative reads	4,019	3,984	2,216	1,275
Missing reads	2,647	2,755	3,849	2,407
Extreme reads	402	401	502	287
No issues	39,979	39,905	51,643	32,356
	Gamma reduced		**Wave 2 non-area 7**	
Zero reads	296	0	996	169
Negative reads	4,105	0	15,165	2,224
Missing reads	2,711	0	11,927	1,924
Extreme reads	371	0	1,333	235
No issues	39,910	0	195,308	30,591
	Gamma electric only		**Wave 3**	
Zero reads	174	153	637	210
Negative reads	1,148	1,148	9,324	3,056
Missing reads	22,956	22,856	10,718	3,599
Extreme reads	224	239	1,204	451
No issues	216	243	131,031	43,463
	Wave 1 dual fuel		**Wave 4**	
Zero reads	1,170	269	636	238
Negative reads	18,294	4,517	6,065	2,254
Missing reads	13,466	3,321	12,053	4,435
Extreme reads	1,380	343	1,019	373
No issues	211,866	53,212	112,088	42,125

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 5		**Wave 8**	
Zero reads	677	160	868	165
Negative reads	13,655	3,180	282	42
Missing reads	13,443	3,207	2,846	454
Extreme reads	3,841	889	613	90
No issues	123,712	29,573	138,819	21,324
	Wave 6		**Wave 9**	
Zero reads	977	164	520	115
Negative reads	7,836	1,183	625	133
Missing reads	30,771	4,716	652	118
Extreme reads	1,287	242	4,968	987
No issues	200,076	32,056	98,628	18,736
	Wave 7			
Zero reads	842	199		
Negative reads	2,496	634		
Missing reads	19,802	5,044		
Extreme reads	2,147	496		
No issues	131,341	33,379		

*PG&E launched Wave 9 in August 2018, so this count represents active customers as of August 2018 instead of January 2018.

Table 11-7. SDG&E data quality summary

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Opower 1		**Opower 3 expansion paper**	
Zero reads	2,961	2,923	25,265	3,153
Negative reads	1,304	1,301	113	12
Missing reads	0	0	0	0
Extreme reads	652	702	2,309	281
No issues	16,313	16,226	168,253	21,282
	Opower 2 low-income		**Opower 4 digital**	
Zero reads	888	223	1,363	346
Negative reads	104	26	1	0
Missing reads	0	0	0	0
Extreme reads	22	12	41	13
No issues	25,096	6,837	61,729	17,036
	Opower 2 non-low-income		**Opower 4 paper**	
Zero reads	3,299	882	3,129	855
Negative reads	883	229	1	0
Missing reads	0	0	0	0
Extreme reads	69	17	426	120
No issues	53,716	14,938	45,195	12,920
	Opower 3 expansion digital		**Opower 5**	
Zero reads	9,660	895	1,802	263
Negative reads	58	8	0	0
Missing reads	0	0	0	0
Extreme reads	194	18	336	62
No issues	256,030	23,772	220,350	34,668

Table 11-8. SCE data quality summary

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Opower 2		**Opower 5**	
Zero reads	437	416	1,337	106
Negative reads	1	1	1	0
Missing reads	0	0	0	0
Extreme reads	700	735	17,228	1,479
No issues	73,889	73,873	583,913	48,498
	Opower 3		**Opower 6**	
Zero reads	560	173	517	41
Negative reads	4	1	0	0
Missing reads	0	0	0	0
Extreme reads	3,739	1,190	4,436	465
No issues	160,527	48,964	441,690	44,455
	Opower 4		**Opower 7**	
Zero reads	1,601	223	343	53
Negative reads	1	0	0	0
Missing reads	0	0	0	0
Extreme reads	24,009	3,422	2,576	385
No issues	240,257	33,495	354,567	48,234

Table 11-9. SCG data quality summary

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 1		**Wave 4**	
Zero reads	2,436	864	2,303	725
Negative reads	4	1	0	0
Missing reads	0	0	0	0
Extreme reads	1	1	4	2
No issues	141,711	58,221	142,577	43,301
	Wave 2		**Wave 5**	
Zero reads	1,642	867	3,425	626
Negative reads	0	0	1	0
Missing reads	0	0	0	0
Extreme reads	1	0	4	1
No issues	102,845	53,533	245,861	44,507
	Wave 3		**Wave 6**	
Zero reads	230	155	444	336
Negative reads	1	0	0	0
Missing reads	0	0	0	0
Extreme reads	0	0	0	0

Data Quality Metric	Treatment Group Customers	Control Group Customers	Treatment Group Customers	Control Group Customers
	Wave 1		Wave 4	
Zero reads	2,436	864	2,303	725
No issues	24,990	16,817	47,426	39,815

11.7 Appendix G: Key inputs for upstream joint savings calculations

The tables in Appendix G present the PA-specific inputs to upstream joint savings calculations. Table 11-10. presents the PG&E-specific inputs. DNV GL retained the uplift (purchase and installation) values from the 2017 online survey for its evaluation of the 2018 program year. Wave 8 and Wave 9, the new waves for the 2018 program year, use the most recently estimated uplift values. Based on the most recent tracking data, less than 1% of PG&E's upstream lighting rebates applied to CFL lamps, so DNV GL applied a value of 0 to PG&E's rebated sales fraction. Additional new values come from DNV GL's 2019 evaluation of the Upstream Lighting Program (ULP), and they include the net-to-gross ratio, the annual electric savings per lamp, the annual interactive gas effects per lamp, the delta watts, and the peak coincidence factor.

Table 11-10. PG&E upstream rebate joint savings calculation inputs

Year	CFL	LED	Source
All waves (prior to 2015): Uplift due to HER			
Year 1	0.95	0.95	2012 PG&E in-home survey
Year 2	0.40	0.40	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: Uplift due to HER			
2015	-0.17	0.09	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.02	0.36	2016-2017 Online Survey (DNV GL, 2019)
Gamma standard: Uplift due to HER			
2015	0.17	0.33	2015 Online Survey (DNV GL, 2017)
2016 - 2018	1.09	-0.53	2016-2017 Online Survey (DNV GL, 2019)
Gamma reduced: Uplift due to HER			
2015	0.01	0.44	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.41	-0.27	2016-2017 Online Survey (DNV GL, 2019)
Gamma electric-only: Uplift due to HER			
2015	-0.07	0.23	2015 Online Survey (DNV GL, 2017)
2016 - 2018	-0.69	1.95	2016-2017 Online Survey (DNV GL, 2019)
Wave 1 dual-fuel: Uplift due to HER			
2015	0.02	0.71	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.13	1.32	2016-2017 Online Survey (DNV GL, 2019)
Wave 1 electric-only: Uplift due to HER			
2015	0.61	0.24	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.13	1.32	2016-2017 Online Survey (DNV GL, 2019)
Wave 2 area 7: Uplift due to HER			
2015	0.02	0.51	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.40	-0.95	2016-2017 Online Survey (DNV GL, 2019)
Wave 2 non-area 7: Uplift due to HER			
2015	0.01	0.55	2015 Online Survey (DNV GL, 2017)
2016 - 2018	-1.14	0.86	2016-2017 Online Survey (DNV GL, 2019)
Wave 3: Uplift due to HER			
2015	0.09	0.09	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.10	0.16	2016-2017 Online Survey (DNV GL, 2019)

Year	CFL	LED	Source
Wave 4: Uplift due to HER			
2015	-0.16	-0.09	2015 Online Survey (DNV GL, 2017)
2016 - 2018	-0.95	-0.28	2016-2017 Online Survey (DNV GL, 2019)
Wave 5: Uplift due to HER			
2015	0	0.11	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.72	-0.28	2016-2017 Online Survey (DNV GL, 2019)
Wave 6: Uplift due to HER			
2015	0.03	0.29	2015 Online Survey (DNV GL, 2017)
2016 - 2018	0.74	-0.03	2016-2017 Online Survey (DNV GL, 2019)
Wave 7: Uplift due to HER			
2017 - 2018	-0.41	-1.08	2016-2017 Online Survey (DNV GL, 2019)
Wave 8: Uplift due to HER			
2018	-0.41	-1.08	2016-2017 Online Survey (DNV GL, 2019)
Wave 9: Uplift due to HER			
2018	-0.41	-1.08	2016-2017 Online Survey (DNV GL, 2019)
All waves: 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 - 2017	0.09	0.20	2015 TRC HER lighting overlap study
2018	0.00	0.20	Tracking Data
All waves: Installed share of 2018			
2011-2017	1	1	Average number of months a lamp would be installed
2018	0.54	0.54	Average number of months a lamp would be installed
All waves: Installation rate			
2011-2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)
2015-2018	1	1	NA
All waves: Net-to-gross ratio			
2011 - 2012	0.63	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2014	0.31	0.45	2013-14 ULP Evaluation (DNV GL, 2016)
2016 - 2017	0.47	0.33	2015 ULP Evaluation (DNV GL, 2017)
2018	0.17	0.83	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual electric savings per lamp (kWh)			
2011	26.8	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2012	26.2	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	23.5	24.8	Program tracking data (DEER 2013-14)
2016 - 2017	16.0	28.5	2015 ULP Evaluation (DNV GL, 2017)
2018	32.5	25.8	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual gas interactive effects per lamp (therms)			
2011 - 2014	-0.78	-0.71	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2017	-0.34	-0.63	2015 ULP Evaluation (DNV GL, 2017)
2018	-0.66	-0.61	2017 ULP Evaluation (DNV GL, 2019)
All waves (except Wave 9): Delta watts			
2011 - 2018	44.4	31.3	2017 ULP Evaluation (DNV GL, 2019)
All waves (except Wave 9): Peak coincidence factor			
2011 - 2018	0.06	0.06	2017 ULP Evaluation (DNV GL, 2019)

Year	CFL	LED	Source
All waves (except Wave 9): Proportion of lamps in place during peak			
2011 - 2017	1	1	Fraction of days before peak period
2018	0.52	0.52	Fraction of days before peak period

Table 11-11. presents the SDG&E-specific inputs to the upstream lighting calculations. DNV GL retained the uplift values from the 2017 online survey for its evaluation of the 2018 program year. Based on the most recent tracking data, less than 1% of SDG&E's upstream lighting rebates applied to CFL lamps, so DNV GL applied a value of 0 to SDG&E's rebated sales fraction. Additional new values come from DNV GL's 2019 evaluation of the Upstream Lighting Program, and they include the net-to-gross ratio, the annual electric savings per lamp, the annual interactive gas effects per lamp, the delta watts, and the peak coincidence factor.

Table 11-11. SDG&E upstream rebate joint savings calculation inputs

Year	CFL	LED	Source
All waves (prior to 2015): Uplift due to HER			
Year 1	0.95	NA	2013 PG&E in-home survey
Year 2	0.40	NA	Interpolated from PG&E and 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)
Opower 1: Uplift due to HER			
2015	0.32	0.20	2015 Online Survey (DNV GL, 2017)
2016 - 2018	-0.30	0.74	2016-2017 Online Survey (DNV GL, 2019)
Opower 2: Uplift due to HER			
2015	-0.07	-0.65	2015 Online Survey (DNV GL, 2017)
2016 - 2018	-0.04	-0.03	2016-2017 Online Survey (DNV GL, 2019)
Opower 3: Uplift due to HER			
2016 - 2018	-0.35	-1.32	2016-2017 Online Survey (DNV GL, 2019)
Opower 4: Uplift due to HER			
2017 - 2018	-0.55	-0.63	2016-2017 Online Survey (DNV GL, 2019)
Opower 5: Uplift due to HER			
2017 - 2018	0.20	0.20	2016-2017 Online Survey (DNV GL, 2019)
All waves: Rebated sales fraction			
2011	0.57	NA	2014 TRC HER lighting overlap study
2012	0.68	NA	2014 TRC HER lighting overlap study
2013	0.40	NA	2014 TRC HER lighting overlap study
2014	0.18	0.32	2014 TRC HER lighting overlap study
2015 - 2017	0.20	0.31	2015 TRC HER lighting overlap study
2018	0.00	0.31	Tracking Data
All waves: Installed share of 2018			
2011-2017	1	1	Average number of months a lamp would be installed
2018	0.54	0.54	Average number of months a lamp would be installed
All waves: Installation rate			
2011-2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)
2015-2018	1	1	NA
All waves: Net-to-gross ratio			
2011 - 2012	0.61	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013	0.30	NA	2013-14 ULP Evaluation (DNV GL, 2016)
2014 - 2015	0.30	0.32	2013-14 ULP Evaluation (DNV GL, 2016)
2016 - 2017	0.80	0.41	2015 ULP Evaluation (DNV GL, 2017)

Year	CFL	LED	Source
2018	0.31	0.68	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual electric savings per lamp (kWh)			
2011	23.3	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2012	22.6	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	17.9	21.8	2014 TRC HER lighting overlap study
2016 - 2017	16.4	27.4	2015 ULP Evaluation (DNV GL, 2017)
2018	29.0	21.3	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual gas interactive effects per lamp (therms)			
2011 - 2014	-0.4	-0.4	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2017	-1.0	-0.5	2015 ULP Evaluation (DNV GL, 2017)
2018	-0.4	-0.4	2017 ULP Evaluation (DNV GL, 2019)
All waves: Delta watts			
2011 - 2018	39.9	26.1	2017 ULP Evaluation (DNV GL, 2019)
All waves: Peak coincidence factor			
2011 - 2018	0.06	0.06	2017 ULP Evaluation (DNV GL, 2019)
All waves: Proportion of lamps in place during peak			
2011 - 2017	1	1	Fraction of days before peak period
2018	0.6	0.6	Fraction of days before peak period

Table 11-12. presents the SCE-specific inputs to the upstream lighting calculations.

Table 11-12. SCE upstream rebate joint savings calculation inputs

Year	CFL	LED	Source
Opower 2: Uplift 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 Results (DNV GL, 2017)
2016-2018	1.09	0.23	2016-2017 Online Survey (DNV GL, 2019)
Opower 3: Uplift due to HER			
			2016-2017 Online Survey (DNV GL, 2019)
Opower 3: Uplift due to HER			
2015 - 2018	0.57	-0.22	
Opower 4: Uplift due to HER			
2017 - 2018	-0.55	-0.63	2016-2017 Online Survey (DNV GL, 2019)
Opower 5: Uplift due to HER			
2017 - 2018	0.20	0.20	2016-2017 Online Survey (DNV GL, 2019)
All waves: Rebated sales fraction			
2011	0.57	NA	2014 TRC HER lighting overlap study
2012	0.68	NA	2014 TRC HER lighting overlap study
2013	0.40	NA	2014 TRC HER lighting overlap study
2014	0.18	0.32	2014 TRC HER lighting overlap study
2015 - 2017	0.20	0.31	2015 TRC HER lighting overlap study
2018	0.00	0.31	Tracking Data
All waves: Installed share of 2018			
2011-2017	1	1	Average number of months a lamp would be installed
2018	0.54	0.54	Average number of months a lamp would be installed
All waves: Installation rate			
2011-2014	0.97	0.99	2013-14 ULP Evaluation (DNV GL, 2016)

Year	CFL	LED	Source
2015-2018	1	1	NA
All waves: Net-to-gross ratio			
2011 - 2012	0.61	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013	0.30	NA	2013-14 ULP Evaluation (DNV GL, 2016)
2014 - 2015	0.30	0.32	2013-14 ULP Evaluation (DNV GL, 2016)
2016 - 2017	0.80	0.41	2015 ULP Evaluation (DNV GL, 2017)
2018	0.31	0.68	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual electric savings per lamp (kWh)			
2011	23.3	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2012	22.6	NA	2010-12 ULP Evaluation (DNV GL, 2014)
2013 - 2015	17.9	21.8	2014 TRC HER lighting overlap study
2016 - 2017	16.4	27.4	2015 ULP Evaluation (DNV GL, 2017)
2018	29.0	21.3	2017 ULP Evaluation (DNV GL, 2019)
All waves: Annual gas interactive effects per lamp (therms)			
2011 - 2014	-0.4	-0.4	2013-14 ULP Evaluation (DNV GL, 2016)
2015 - 2017	-1.0	-0.5	2015 ULP Evaluation (DNV GL, 2017)
2018	-0.4	-0.4	2017 ULP Evaluation (DNV GL, 2019)
All waves: Delta watts			
2011 - 2018	39.9	26.1	2017 ULP Evaluation (DNV GL, 2019)
All waves: Peak coincidence factor			
2011 - 2018	0.06	0.06	2017 ULP Evaluation (DNV GL, 2019)
All waves: Proportion of lamps in place during peak			
2011 - 2017	1	1	Fraction of days before peak period
2018	0.6	0.6	Fraction of days before peak period

11.8 Appendix H: Total program savings by wave

Table 11-13. PG&E per household electric savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Down-stream	Joint Up-stream	Adjusted	Unadjusted	Adjusted
Electric (kWh)							
Beta	8,801	226	2	11	212	2.6%	2.4%
Gamma standard	6,221	109	<1	7	102	1.8%	1.6%
Gamma reduced	6,221	90	0	8	82	1.4%	1.3%
Gamma electric-only	6,431	121	3	19	99	1.9%	1.5%
Wave 1 dual fuel	6,203	91	1	17	73	1.5%	1.2%
Wave 1 electric-only	7,031	105	<1	16	88	1.5%	1.3%
Wave 2 area 7	5,521	101	<1	0	101	1.8%	1.8%
Wave 2 non-area 7	5,992	124	<1	6	117	2.1%	2.0%
Wave 3	6,011	91	2	3	87	1.5%	1.4%
Wave 4	5,545	56	<1	0	56	1.0%	1.0%
Wave 5	8,111	107	<1	0	106	1.3%	1.3%
Wave 6	5,809	72	<1	1	71	1.2%	1.2%
Wave 7	6,314	72	0	0	72	1.1%	1.1%
Wave 8	2,604	24	0	0	24	0.9%	0.9%
Wave 9	3,435	13	0	0	13	0.4%	0.4%

Table 11-14. PG&E per household gas savings

Wave	Baseline Consumption					% Savings	
		Unadjusted	Joint Downstream	Joint Upstream	Adjusted	Unadjusted	Adjusted
Gas (therms)							
Beta	702	6	0	>-1	7	0.9%	1.0%
Gamma standard	405	3	<1	>-1	4	0.8%	0.9%
Gamma reduced	405	2	0	>-1	2	0.5%	0.6%
Wave 1 dual fuel	419	4	0	>-1	4	0.9%	1.0%
Wave 2 area 7	469	5	0	0	5	1.0%	1.0%
Wave 2 non-area 7	426	3	0	>-1	4	0.8%	0.8%
Wave 3	428	4	0	>-1	4	0.8%	0.8%
Wave 4	393	2	0	0	2	0.5%	0.5%
Wave 5	489	4	0	0	4	0.7%	0.7%
Wave 6	398	2	0	>-1	2	0.5%	0.5%
Wave 7	411	3	<1	0	3	0.7%	0.7%
Wave 8	251	2	<1	0	2	0.7%	0.7%
Wave 9	177	1	<1	0	1	0.7%	0.7%

Table 11-15. SDG&E per household electric and gas savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Down-stream	Joint Up-stream	Adjusted	Unadjusted	Adjusted
Electric (kWh)							
Opower 1	8,416	108	0	17	91	1.3%	1.1%
Opower 2 Low Income	5,536	66	6	0	60	1.2%	1.1%
Opower 2 Non-Low Income	5,151	90	0	0	90	1.7%	1.7%
Opower 3 Expansion Digital	5,284	67	0	0	67	1.3%	1.3%
Opower 3 Expansion Paper	9,758	145	<1	0	144	1.5%	1.5%
Opower 4 Digital	4,851	51	0	0	51	1.1%	1.1%
Opower 4 Paper	8,461	136	0	0	136	1.6%	1.6%
Opower 5	3,997	29	<1	<1	28	0.7%	0.7%
Gas (therms)							
Opower 1	559	6	0	<1	7	1.1%	1.2%
Opower 2 Low Income	298	1	<1	0	1	0.5%	0.4%
Opower 2 Non-Low Income	287	<1	0	0	<1	0.3%	0.3%
Opower 3 Expansion Digital	295	2	0	0	2	0.8%	0.8%
Opower 3 Expansion Paper	433	6	<1	0	5	1.3%	1.2%
Opower 4 Digital	277	2	<1	0	2	0.7%	0.6%
Opower 4 Paper	395	2	<1	0	2	0.6%	0.6%
Opower 5	249	2	0	<1	2	1.0%	1.0%

Table 11-15. SCE per household electric savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Down-stream	Joint Up-stream	Adjusted	Unadjusted	Adjusted
Electric (kWh)							
Opower 2	7,593	92	4	32	56	1.2%	0.7%
Opower 3	8,634	128	<1	14	113	1.5%	1.3%
Opower 4	12,163	161	1	0	159	1.3%	1.3%
Opower 5	8,993	121	<1	0	121	1.3%	1.3%
Opower 6	4,752	31	<1	0	31	0.7%	0.7%
Opower 7	1,429	5	<1	0	5	0.4%	0.4%

Table 11-16. SCG per household gas savings

Wave	Baseline Consumption	Per Household Savings				% Savings	
		Unadjusted	Joint Down-stream	Joint Up-stream	Adjusted	Unadjusted	Adjusted
Gas (therms)							
Wave 1	459	7	0	NA	7	1.6%	1.6%
Wave 2	464	7	0	NA	7	1.4%	1.4%
Wave 3	454	5	0	NA	5	1.1%	1.1%
Wave 4	490	8	0	NA	8	1.7%	1.7%
Wave 5	477	5	0	NA	5	1.1%	1.1%
Wave 6a	469	7	0	NA	7	1.4%	1.4%
Wave 6b	484	8	0	NA	8	1.7%	1.7%

Table 11-17. PGE total electric and gas savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Beta	8,570,816	77,527	435,230	8,058,059
Gamma standard	4,732,630	13,714	307,568	4,411,348
Gamma reduced	3,895,389	0	344,151	3,551,238
Gamma electric-only	2,489,259	52,118	397,590	2,039,550
Wave 1 dual fuel	20,466,413	259,697	3,775,179	16,431,537
Wave 1 electric-only	2,139,807	17,855	326,278	1,795,674
Wave 2 area 7	5,358,361	26,475	0	5,331,886
Wave 2 non-area 7	25,571,399	100,234	1,323,814	24,147,351
Wave 3	12,408,733	224,196	363,916	11,820,621
Wave 4	6,397,623	5,840	0	6,391,783
Wave 5	14,408,621	120,264	0	14,288,357
Wave 6	14,156,111	7,047	202,244	13,946,820
Wave 7	9,035,212	0	0	9,035,212
Wave 8	3,127,076	0	0	3,127,076
Wave 9	1,238,920	0	0	1,238,920
Gas (therms)				
Beta	246,935	0	-12,325	259,260
Gamma standard	149,019	543	-9,358	157,834
Gamma reduced	95,797	0	-10,336	106,133
Wave 1 dual fuel	834,447	0	-98,187	932,634
Wave 2 area 7	250,669	0	0	250,669
Wave 2 non-area 7	705,387	0	-34,271	739,659
Wave 3	484,583	0	-9,742	494,325
Wave 4	244,368	0	0	244,368
Wave 5	492,285	0	0	492,285
Wave 6	422,153	0	-4,368	426,520
Wave 7	340,518	141	0	340,378
Wave 8	212,578	49	0	212,529
Wave 9	112,961	6	0	112,955

Table 11-18. PG&E total peak demand savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Peak demand (kW)				
Beta	2,093.6	53.5	40.7	1,999.3
Gamma standard	1,550.1	28.2	39.1	1,482.8
Gamma reduced	1,380.4	0.0	37.6	1,342.8
Gamma electric-only	640.8	87.7	30.3	522.7
Wave 1 dual fuel	2,155.8	122.6	313.8	1,719.3
Wave 1 electric-only	381.9	8.1	27.5	346.3
Wave 2 area 7	1,449.4	14.7	0	1,434.7
Wave 2 non-area 7	5,865.4	20.9	70.9	5,773.6
Wave 3	2,508.7	129.3	32.1	2,347.2
Wave 4	965.3	80.1	0	885.2
Wave 5	3,782.9	98.5	11.6	3,672.8
Wave 6	7,760.1	102.2	32.8	7,625.1
Wave 7	609.7	0.0	0	609.7
Wave 8	248.0	0.7	0	247.2
Wave 9	NA	NA	NA	NA

Table 11-19.SDG&E total electric, gas, and peak demand savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Opower 1	1,287,627	0	198,678	1,088,949
Opower 2 Low Income	971,775	84,727	0	887,048
Opower 2 Non-Low Income	2,912,199	0	0	2,912,199
Opower 3 Expansion Digital	10,620,584	0	0	10,620,584
Opower 3 Expansion Paper	21,608,736	148,370	0	21,460,366
Opower 4 Digital	2,097,278	0	0	2,097,278
Opower 4 Paper	5,302,619	0	0	5,302,619
Opower 5	5,649,123	155,140	113,761	5,380,222
Gas (therms)				
Opower 1	56,300	0	-2,904	59,204
Opower 2 Low Income	14,447	2,290	0	12,157
Opower 2 Non-Low Income	21,184	0	0	21,184
Opower 3 Expansion Digital	259,942	0	0	259,942
Opower 3 Expansion Paper	439,320	41,033	0	398,287
Opower 4 Digital	44,505	2,455	0	42,050
Opower 4 Paper	55,881	4,143	0	51,738
Opower 5	291,958	0	-2,346	294,305
Peak Demand (kW)				
Opower 1	136.7	0.0	15.0	121.7
Opower 2 Low Income	-2.1	0.0	0.0	0.0
Opower 2 Non-Low Income	466.7	0.0	0.0	466.7
Opower 3 Expansion Digital	2,105.4	0.0	0.0	2,105.4
Opower 3 Expansion Paper	3,858.9	203.5	0.0	3,655.5
Opower 4 Digital	764.7	0.0	0.0	764.7
Opower 4 Paper	599.8	81.8	0.0	518.0
Opower 5	899.2	644.4	1.8	253.0

Table 11-20. SCE total electric and peak demand savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Electric (kWh)				
Opower 2	5,417,503	234,224	1,883,635	3,299,643
Opower 3	17,124,695	85,562	1,892,448	15,146,685
Opower 4	32,993,699	277,427	0	32,716,273
Opower 5	62,279,553	314,764	0	61,964,789
Opower 6	13,040,336	0	0	13,040,336
Opower 7	1,727,626	0	0	1,727,626
Peak Demand (kW)				
Opower 2	1,874.2	88.5	137.6	1,648.1
Opower 3	3,985.2	92.8	139.2	3,753.2
Opower 4	5,370.3	36.4	0	5,333.9
Opower 5	11,111.7	0	0	11,111.7
Opower 6	6,780.4	0	0	6,780.4
Opower 7	NA	NA	NA	NA

Table 11-21. SCG total gas savings by wave

Wave	Program Total			
	Unadjusted	Joint Downstream	Joint Upstream	Adjusted
Gas (therms)				
Opower 1	1,053,787	1,199	NA	1,052,587
Opower 2	679,740	1,827	NA	677,913
Opower 3	124,866	0	NA	124,866
Opower 4	1,194,109	0	NA	1,194,109
Opower 5	1,328,841	0	NA	1,328,841
Opower 6a	240,740	0	NA	240,740
Opower 6b	95,108	1,867	NA	93,241

11.9 Appendix I: HER savings by PA from 2011 to 2018

Table 11-22. Historical HER electric and gas savings per household across PAs from 2011 to 2018

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%

PA	Wave	No. of Treatment Months	Unadjusted kWh Savings per Household	Percent kWh Savings	Unadjusted therms Savings per Household	Percent therms Savings
	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%
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%
2017						
PG&E	Beta	12	220	2.3%	6	0.8%

PA	Wave	No. of Treatment Months	Unadjusted kWh Savings per Household	Percent kWh Savings	Unadjusted therms Savings per Household	Percent therms Savings
	Gamma Dual Standard	12	95	1.4%	2	0.5%
	Gamma Dual Reduced	12	72	1.1%	2	0.5%
	Gamma Electric only	12	122	1.8%	NA	NA
	Wave One Dual	12	107	1.6%	3	0.8%
	Wave One Electric only	12	91	1.2%	NA	NA
	Wave Two Area 7	12	105	1.8%	5	1.0%
	Wave Two Not Area 7	12	116	1.8%	3	0.7%
	Wave Three	12	81	1.3%	2	0.5%
	Wave Four	12	58	1.0%	2	0.6%
	Wave Five	12	113	1.3%	3	0.6%
	Wave Six	12	55	0.9%	2	0.6%
	Wave Seven	10	44	0.8%	1	0.5%
SCE	Opower 2	12	103	1.3%	NA	NA
	Opower 3	12	138	1.6%	NA	NA
	Opower 4	12	153	1.2%	NA	NA
	Opower 5	9	65	0.9%	NA	NA
SDG&E	Opower 1	12	80	1.0%	6	1.2%
	Opower 2 Low Income	12	39	0.8%	1	0.5%
	Opower 2 Non-Low Income	12	75	1.6%	<1	0.3%
	Opower 3 Expansion Digital	12	61	1.3%	3	1.0%
	Opower 3 Expansion Paper	12	130	1.4%	4	1.1%
	Opower 4 Digital	8	22	0.7%	<1	0.0%
	Opower 4 Paper	8	46	0.8%	1	0.6%
	Opower 5	1	<1	0.1%	<1	0.0%
2018						
PG&E	Beta	12	226	2.6%	6	0.9%
	Gamma Dual Standard	12	109	1.8%	3	0.8%
	Gamma Dual Reduced	12	90	1.4%	2	0.5%
	Gamma Electric only	12	121	1.9%	NA	NA
	Wave One Dual	12	91	1.5%	4	0.9%
	Wave One Electric only	12	105	1.5%	NA	NA
	Wave Two Area 7	12	101	1.8%	5	1.0%
	Wave Two Not Area 7	12	124	2.1%	3	0.8%
	Wave Three	12	91	1.5%	4	0.8%
	Wave Four	12	56	1.0%	2	0.5%
	Wave Five	12	107	1.3%	4	0.7%
	Wave Six	12	72	1.2%	2	0.5%

PA	Wave	No. of Treatment Months	Unadjusted kWh Savings per Household	Percent kWh Savings	Unadjusted therms Savings per Household	Percent therms Savings
	Wave Seven	12	72	1.1%	3	0.7%
	Wave Eight	12	24	0.7%	2	0.6%
	Wave Nine	5	13	0.4%	1	0.7%
SCE	Opower 2	12	92	1.2%	NA	NA
	Opower 3	12	128	1.5%	NA	NA
	Opower 4	12	161	1.3%	NA	NA
	Opower 5	12	121	1.3%	NA	NA
	Opower 6	10	31	0.7%	NA	NA
	Opower 7	11	5	0.4%	NA	NA
SDG&E	Opower 1	12	108	1.3%	6	1.1%
	Opower 2 Low Income	12	66	1.2%	1	0.5%
	Opower 2 Non-Low Income	12	90	1.7%	<1	0.3%
	Opower 3 Expansion Digital	12	67	1.3%	2	0.8%
	Opower 3 Expansion Paper	12	145	1.5%	6	1.3%
	Opower 4 Digital	12	51	1.1%	2	0.7%
	Opower 4 Paper	12	136	1.6%	2	0.6%
	Opower 5	12	29	0.7%	2	1.0%
SCG	Wave 1	12	NA	NA	7	1.6%
	Wave 2	12	NA	NA	7	1.4%
	Wave 3	12	NA	NA	5	1.1%
	Wave 4	12	NA	NA	8	1.7%
	Wave 5	12	NA	NA	5	1.1%
	Wave 6a	12	NA	NA	7	1.4%
	Wave 6b	12	NA	NA	8	1.7%

11.10 Appendix J: Response to comments

Response ID	Commenter	Comment	Response
1	PG&E	Nexant continues to use a lagged-dependent variable (LDV) model in this evaluation and believes this is a reasonable methodology. In the current statewide workpaper for HER, SWWB004-01, the methodology specified to estimate electric and gas savings is a fixed-effects panel regression model that used by DNV GL in the 2018 evaluation, and the workpaper states that "such a model is the standard for evaluating behavioral programs." This workpaper does acknowledge that a LDV model is also valid (see footnote 11)," but that a single methodological approach is presented for the purpose of simplicity and consistency.	Noted. Thank you.
2	PG&E	In order to maintain the validity of the RCT, DNV GL does not remove HER recipients who opt to stop receiving reports as this impacts the treatment group but not the control group. Treatment for these customers is considered the "intent to treat". DNV GL removes customers (both treatment and control) who drop out of the HER program by moving (attrition) in the month they move as move-outs are assumed to affect both treatment and control equally. Nexant used a similar approach.	Noted. Thank you.
3	PG&E	As the basis for the following regression model, DNV GL uses the 15- and 60-minute interval data from 2 p.m. to 5 p.m. during the optimal HW in each HER program year. The model produces estimates of peak demand savings due to the HERs. Nexant used a similar approach.	Noted. Thank you.
4	PG&E	DNV GL's unadjusted electric energy savings estimate is 3.52% higher than Nexant's, which is reasonable and similar to previous years.	Noted. Thank you.
5	PG&E	DNV GL's unadjusted electric energy savings estimate for Wave 1 Electric Only is 114% higher than Nexant's estimate, which is concerning. However, Nexant's estimate falls within the 90% CI of DNV GL's estimate. Similar differences have been found in previous years, and further investigation may be worthwhile.	Noted. We find that the differences are mostly due to differences in the savings per household. Our PY2018 estimated savings per household is in line with past evaluations. We agree further investigation during future evaluations may be worthwhile.
6	PG&E	DNV GL's unadjusted natural gas energy savings estimate is 6.6% smaller than Nexant's, which may be cause for concern. However, Nexant's wave-level estimates fall within the 90% CI of DNV GL's estimates. This percent difference is similar to previous years.	Noted. Since Nexant's wave level estimates fall within the 90% CI of DNV GL's estimates and the differences are similar to previous years, the total savings difference is unlikely to be statistically different. It may be worthwhile to explore these differences further in future evaluations.
7	PG&E	Nexant determined the same heatwave for 2018.	Noted. Thank you.

Response ID	Commenter	Comment	Response
8	PG&E	This estimate is 15% greater than Nexant's estimate. In 2017, DNV GL's estimate was 13% greater than Nexant's, but much of this 2017 difference can be explained by a difference in customer counts. This is not true for 2018, as the difference in customer counts is only about 1%. We attribute the difference to the fact that the pre-treatment peak periods selected by DNV GL are different from those selected by Nexant (see comments). Given how variable customer loads are at any given time, Nexant's use of a different period as the pre-treatment value is one likely source of the difference in final MW savings estimates.	We agree with this assessment. Thank you.
9	PG&E	One key area we identify as requiring close collaboration for the upcoming year is the incorporation of HER load shapes developed by DNV GL into the avoided cost calculator to compute the cost-effectiveness of the HER program. These empirically-derived load shapes should be incorporated into DEER and replace the weighted blend of DEER load shapes currently in use. Thereafter, a process should be developed for these load shapes to be refreshed on a regular cadence.	Noted. We look forward to working with the CPUC and PAs on this as well.
10	SCE	1. Correction: Table 6.1 SCE HER Waves, program year 2018. All of SCE's HER Waves (2 through 7) receive Quarterly Printed HERs and Emails Monthly, not only wave 7. Emails are sent to individuals where an email address is available.	Edits made to reflect this in the report. Thank you.
11	SCE	2. SCE believes that distributional analysis would have been very valuable to investigate. The report does not discuss the distributional effect of HER program which would have been more nuanced and helpful in understanding the impact. Who are the savers and who are non-savers? The average treatment effects are not the best estimate when there are large sample sizes – averages reduce an entire impact distribution to a single number and heterogeneity in treatment effects will gone unnoticed. This and similar exercise would have increased IOUs ability of understanding their customers and recommendations would be more customized, etc.	Per discussion with stakeholders at the Residential PCG II call in October 2019 and email exchange dated 10/25/2019 between SCE and DNV GL (where all stakeholders are copied), DNV GL dropped this analysis as we received input that this was duplicative of parallel efforts being undertaken in PA-led studies on this topic.