REPORT

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PG&E HER 2018 Energy and Demand Savings Early EM&V

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1 Executive Summary

This report documents the energy and demand savings resulting from the Home Energy Reports (HERs) Program administered by Pacific Gas and Electric Company (PG&E) for 2018. It includes estimated energy savings impacts from a study of the persistence of the treatment effect over time (after reports are no longer provided to customers) and incremental savings from electronic delivery of HERs (eHERs) provided as a supplement to the standard reports delivered by mail. The experimental waves that are included in this report are outlined in Table 1-1. All experimental waves have remained in the field since their initial launch.[1]

Table 1-1: Experimental Waves in Field in 2018

Experimental Wave	Energy Usage Quartiles	Treatment[2]	Control	First Report Generated
Beta	Top 1	60,000	60,000	7/2011
Gamma Standard Dual	All Quartiles	72,000	72,000	11/2011
Gamma Reduced Dual	All Quartiles	72,000	72,000	11/2011
Gamma All Electric	All Quartiles	45,000	45,000	11/2011
Gamma Gas Only	All Quartiles	15,000	15,000	11/2011
Wave 1	Top 3	360,000	90,000	3/2012
Wave 1 All Electric	Top 3	40,000	10,000	3/2012
Wave 2 Area 7[3]	Top 3	80,000	50,000	2/2013
Wave 2 Not Area 7	Top 3	305,000	48,000	2/2013
Wave 3	Top 3	225,000	75,000	7/2013
Wave 4	Top 3	200,000	75,000	3/2014
Wave 5	Top 2	210,000	50,000	10/2014
Wave 6	Top 3	312,000	50,000	9/2015
Wave 7	Top 3	157,500	40,000	3/2017
Wave 8	Top 15 16ths	143,000	22,000	11/2017
Wave 9	Top 2	105,000	20,000	9/2018

[1] Additional information about the Home Energy Reports measure is contained in its work paper, Statewide Measure ID SWWB004-01, available from http://www.deeresources.net/workpapers.

[2] Customer counts presented in this table represent the number of customers assigned to treatment and control when the wave was launched, not the number of customers included in the analysis presented in this report.

[3] PG&E's service territory is divided into 7 service areas. Area 7, located in the north coast, was not planned to be included in the Wave 2 sample frame initially. When it was decided to be included subsequently, a separate experiment was launched concurrently for this service area.

This report is organized as follows: Section 2 summarizes the aggregate and monthly electric and gas savings resulting from the HER program in 2018; Section 3 documents the methodology, calculations, and resulting estimates for peak megawatt load reduction resulting from the HER program for 2018; Section 4 contains the results from the fifth year of the Persistence Study including gas and electric results; and Section 5 provides the results from the eHER test and also includes gas and electric results.

2 Energy Savings

Nexant estimated energy savings resulting from PG&E's Home Energy Reports Program for 2018 as part of its contract to provide early measurement and verification (early M&V) of the HERs Program. Early M&V provides an independent estimate of savings to substantiate PG&E's energy savings claims made to the California Public Utilities Commission. Early M&V also seeks to validate key savings assumptions and better understand how savings are achieved for the purpose of improving programs.

The methodology developed to estimate the savings resulting from PG&E's HERs initiative is documented in a report published by Freeman, Sullivan and Company (now Nexant) in 2013.[4] This report documents the HER evaluation design, participant and control group selection, initial energy savings estimation methodology, and the initial field research and analysis employed to avoid double-counting of savings resulting from the uptake of other measures in the portfolio as a result of assignment to a treatment group (that is, exposure to the reports). Subsequent early M&V reports published by Nexant in subsequent years document methodological refinements and other improvements in the evaluation of PG&E's Home Energy Reports Program.

The methodology used to estimate energy savings resulting from HERs for 2018 is the same as that used by Nexant for 2017 with one key difference. In the 2017 evaluation, customers who, subsequent to random assignment (to treatment or control), became ineligible for HER participation prior to the launch of the wave (experiment) were excluded from the analysis. This "post-assignment, pre-launch" customer exclusion, was applied to all HER waves in field in 2017 because the data had already been pulled by PG&E and delivered to Oracle for another purpose. It was not applied in previous evaluations and was not applied in the present (2018) evaluation, as the data provided was tailor to Nexant's specific data request.

Program impacts on electricity consumption were estimated using a lagged dependent variable model in which monthly energy consumption for treatment and control customers was estimated using consumption data from the pretreatment period.[5] The regression specification is presented in Equation 1 with definitions for each term shown in Table 2-1.

[4] Evaluation of Pacific Gas and Electric Company's Home Energy Report Initiative for the 2010-2012 Program (2013). Freeman, Sullivan, and Co. CALMAC ID 0329.01.

[5] A fixed-effects panel regression model in which monthly energy consumption for treatment and control group customers is estimated using an indicator variable for month of the study, a treatment month indicator variable and a customer-level indicator variable is an alternative methodology frequently used to determine impacts of similar programs. It produces a "difference-in-difference" calculation by comparing the pre- to post-treatment difference for the treatment group to the pre- to post-treatment difference for the control group.

Equation 1: Regression Specification

$$kWh_{it} = a + b_t + c_t \cdot treatment_i + d \cdot pretreatment\_kwh_{it} + e_t \cdot pretreatment\_kwh_{it} + \varepsilon_{it}$$

Table 2-1: Lagged Dependent Variable Model Definitions

Variable	Definition
kWh_{it}	Customer *i*'s usage in month *t*.
a	The estimated constant for energy consumption (average for all customers in all periods).
b_t	The estimated coefficient for the month indicator variable.
c_t	The estimated coefficient for the month indicator variable for treatment customers. This is the treatment effect for a particular month *t*.
$treatment_i$	The treatment indicator variable for customer *i*. Equal to 1 for treatment customers and 0 otherwise.
d	The estimated coefficient for pretreatment consumption.
$pretreatment\_kwh_{it}$	Pretreatment usage for customer *i* for month *t*. Pretreatment consumption for a particular month in the post treatment period refers to the same calendar month in the pretreatment period.
e_t	The estimated coefficient for pretreatment consumption on a particular month *t*.
ε_{it}	The error term.

This specification applies to all experimental waves, with fewer months included in the model for the wave that began during 2018 given the shorter time between the launch of the experiment and the end of the year.[6] Estimates were created separately for each month to account for differences in behavior throughout the calendar year and for the purposes of observing trends in treatment effects over time. For each customer, the model incorporated one year of pre-treatment billing data. Standard errors were estimated to allow for arbitrary correlation among errors within each customer's data.

The impacts for each experimental wave of the HER program were estimated separately (i.e., unique model coefficients were calculated for each wave), and within each wave the savings for each fuel type (gas, electric, or both) were calculated independently. This approach was used because there are inherent differences between dual-fuel and single-fuel customers that would add noise to an aggregate analysis and because one purpose of the experiments was to test for these differences.

[6] This specification is a recommended specification for estimating treatment effects in this context. See equation 1.3, page 76 of "Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations," published by SEE Action, May 2012. Available at https://emp.lbl.gov/sites/all/files/behavior-based-emv-ppt.pdf

There are two key points to note regarding the comparability of treatment and control groups:

- First, it is assumed that receiving HERs does not affect the rate at which customers close their accounts. This appears to be true given the nearly identical attrition rate between the treatment and control groups. Customers who close their accounts are retained in each sample until their close date. Consequently, the populations of interest for each experimental wave grow smaller for both treatment and control groups as time progresses.

- Second, in order to maintain comparability, opt-outs (that is, customers assigned to treatment groups who make a request to stop receiving reports) are retained in their treatment groups for the entire analysis year. There are two reasons that underlie this decision:

    - First, because the experiment uses an opt-out delivery design (treatment households receive the reports without initially requesting them), any households that opt out have received at least one report. Strictly speaking, this means they have been treated.

    - Second, there is no way to identify households in the control group who would have opted out of the program: Removing the opt-outs from only the treatment group compromises the internal validity of the savings estimates, and so they are retained throughout the analysis dataset.[7]

2.1 Aggregate and Adjusted Savings Claims

The aggregate electric and gas savings claims are calculated using output from the regression models described in Section 2. These savings estimates are shown by experimental wave in Table 2-2 on the following page. When HER savings are calculated, they include savings already potentially claimed by other (non-HER) programs in PG&E's residential portfolio (joint savings). The table also displays the total estimated impact of the HER program for 2018, both before (aggregate) and after (adjusted) applying an adjustment for joint savings.

[7] In practice, the proportion of customers opting out of HER treatment is negligible (less than 0.5%).

Table 2-2: January 2018 through December 2018 HER Savings

Experimental Wave			Electric (in GWh)	Standard Error	Gas (in ,000 thms)	Standard Error
Beta			8.6	1.1	287	61
Gamma	**Dual**	**Standard**	4.0	0.9	145	44
		Reduced	3.7	0.9	96	40
	Electric-Only		2.7	0.6	-	-
	Gas-Only		-	-	8.7	-
Wave One	**Dual**		21.5	3.0	874	139
	Electric-Only		1.0	1.1	-	-
Wave Two	**Not Area 7**		24.5	3.2	796	164
	Area 7		5.1	0.9	287	53
Wave Three			12.4	2.1	554	104
Wave Four			6.5	1.7	340	85
Wave Five			12.6	2.9	393	136
Wave Six			14.9	3.0	474	151
Wave Seven			8.5	1.8	311	89
Wave Eight			3.0	0.7	258	66
Wave Nine			0.9	0.6	100	42
Total			129.8	7.3	4,926	360
Adjustment for Upstream			-5.5	–	138	–
Adjustment for Downstream			-1.3	–	-13	–
Adjusted Total			123.0	–	5,050	–

The potentially double-counted downstream energy savings result from various energy efficiency programs offered by PG&E through which customers received rebates for purchasing and installing energy efficient equipment (such as variable-speed pool pumps and through participation in a home upgrade program). PG&E receives credit for the savings achieved by these programs through a separate savings claim process. In this report, electric savings from these programs were calculated for each customer who received a rebate by multiplying the number of days in 2018 since installation occurred (as determined by PG&E's MDSS system data) by an estimate of the device's daily electric savings. This estimate, as determined by DEER load profiles for each measure, is dependent on the time of year the device is active: for example, an efficient AC unit would have much lower savings in December (low use) than in July (high use). Additionally, installed measures are assumed to achieve savings only during their effective useful lifetime (EUL). The per-customer energy savings for rebated measures for the treatment group is subtracted from the control group savings to estimate the total double counted downstream savings per customer. This value is then multiplied by the number of treatment customers in 2018 to estimate the program-level adjustment.

This same methodology was used in the 2015, 2016, and 2017 early M&V reports, in which the total estimated double-counted downstream savings were 2.4, 0.8, and 1.3 GWh, respectively.

These comparatively low values, as compared to the magnitude of program savings, underscore the diminishing size of the downstream residential measure portfolio. The estimate of double-counted therm savings was calculated using the same methodology and resulted in a total double-counting estimate of 13,000 therms. This is a small adjustment when compared to the total gas energy savings attributed to the HER program.

Upstream programs, principally the Upstream Lighting Program (ULP), present a unique challenge in the estimation of potentially double-counted savings because participation in these programs is not tracked at the customer level, and therefore cannot be tied back to participation in HER treatment and control households for comparison. In this evaluation, we use the findings of previous research in this area to assume likely spillover into PG&E's ULP; no new research was conducted for this purpose.

The analysis presented in this section accounts for the potential overlap in electric savings claims between the HER program and the ULP, as well as the increase in heating load caused by lower heat emissions from the replacement of less efficient bulbs with CFLs and LEDs. The equation for estimating upstream joint savings and gas interactive effects for each month since the onset of treatment is shown in Equation 2. Joint savings are estimated separately for each wave, treatment month, and bulb type (CFL or LED). The equation inputs and sources of those inputs can be found in Appendix A.

Equation 2: Monthly Joint Savings Estimate

$$\begin{aligned} &Additional\ kWh\ or\ therm\ effects\ attributable\ to\ ULP \\ &= kWh\ or\ therm\ effects\ per\ bulb \times additional\ bulbs\ per\ treatment\ customer \\ &\times percent\ of\ bulbs\ installed\ per\ month\ in\ 2018 \\ &\times percent\ of\ bulb\ sales\ that\ received\ rebates \times installation\ rate \times NTG \end{aligned}$$

The total estimated double-counted upstream electric savings was 5.5 GWh. The adjustment to gas savings was equal to an increase of 138,000 therms.

Table 2-3 and Table 2-4 show the inputs to the aggregate savings values presented in Table 2-2 for electric and gas savings estimates, respectively. These tables show the number of treatment months, the estimated percentage impact,[8] the average monthly energy usage in the control group during 2018, and the yearly average number of customers in each wave. Multiplying these values together gives the estimated GWh (or 1,000 therms) of savings for each wave, as shown in the right-most column of each table.

[8] In the actual calculation, the regression produces a kWh value rather than a percentage value. The kWh value is used directly rather than using a percentage applied to a control load. The percentage and the average load are presented here for illustrative purposes.

Table 2-3: Primary Inputs into the Electric Savings Estimates

Wave	# of Treatment Months	# of Treatment Months in 2018	% Impact	Average Monthly Control Load (kWh)	Average # of Treatment Customers	Aggregate GWh Impact
Beta	89	12	2.7%	732.2	36,512	8.6
Gamma Dual Standard	86	12	1.5%	517.7	41,935	4.0
Gamma Dual Reduced	86	12	1.4%	517.6	41,969	3.7
Gamma Electric-only	86	12	2.2%	533.7	19,883	2.7
Wave One Dual	83	12	1.6%	516.9	219,642	21.5
Wave One Electric-only	83	12	0.7%	585.0	19,898	1.0
Wave Two Non-Area 7	71	12	2.1%	500.1	198,819	24.5
Wave Two Area 7	71	12	1.8%	461.5	51,463	5.1
Wave Three	66	12	1.5%	501.0	132,881	12.4
Wave Four	58	12	1.1%	462.2	110,372	6.5
Wave Five	51	12	1.2%	674.5	130,449	12.6
Wave Six	40	12	1.3%	483.4	191,137	14.9
Wave Seven	22	12	1.1%	525.5	123,720	8.5
Wave Eight	14	12	0.9%	217.2	127,996	3.0
Wave Nine	4	4	0.4%	634.2	96,929	0.9
Total					**1,543,602**	**129.8**

Table 2-4: Primary Inputs into the Gas Savings Estimates

Wave	# of Treatment Months	# of Treatment Months in 2018	% Impact	Average Monthly Control Load (Therms)	Average # of Treatment Customers	Aggregate ,000 Therm Impact
Beta	89	12	1.1%	58.1	36,459	287
Gamma Dual Standard	86	12	0.7%	34.1	50,622	145
Gamma Dual Reduced	86	12	0.6%	33.6	41,959	96
Wave One Dual	83	12	1.0%	34.9	219,420	874
Wave Two Non-Area 7	71	12	0.9%	35.7	198,707	796
Wave Two Area 7	71	12	1.2%	39.4	51,533	287
Wave Three	66	12	1.0%	35.8	132,862	554
Wave Four	58	12	0.8%	32.8	110,298	340
Wave Five	51	12	0.6%	40.8	130,362	393
Wave Six	40	12	0.6%	33.2	191,051	474
Wave Seven	22	12	0.6%	34.5	123,710	311
Wave Eight	14	12	0.8%	21.1	127,918	258
Wave Nine	4	4	0.7%	39.5	97,227	100
Total					**1,512,126**	**4,917**

2.2 Electricity Savings Observed by Month

This sub-section presents a brief discussion of the electric savings achieved in 2018 by wave. One trend observable in the data is the impact of length of exposure to the reports on savings: with some exceptions, the waves in the field for longer lengths of time tend to save more electricity. The composition of the waves is not static, and these differences explain part of the variations observed. Table 2-5 presents the average percentage impact by month and the average monthly impact through the end of 2018 for each wave of the HER program.

Table 2-5: Average Percentage Impact on Electricity Usage by Wave

Month	Beta	Gamma			Wave One		Wave Two		Wave Three	Wave Four	Wave Five	Wave Six	Wave Seven	Wave Eight	Wave Nine
		Dual		Electric-Only	Dual	Electric-Only	Not Area 7	Area 7							
		Standard	Reduced												
Jan-18	2.3%	1.7%	1.3%	2.5%	1.5%	1.1%	1.3%	1.5%	1.4%	1.0%	0.9%	0.8%	1.0%	1.0%	---
Feb-18	2.5%	1.9%	1.1%	2.9%	1.8%	1.7%	1.7%	1.7%	1.5%	1.1%	1.2%	0.9%	1.4%	0.8%	---
Mar-18	2.4%	1.9%	1.5%	2.3%	1.6%	1.5%	1.9%	2.0%	1.5%	0.9%	1.0%	1.0%	1.2%	0.7%	---
Apr-18	2.9%	2.0%	2.1%	2.6%	1.8%	1.1%	2.5%	2.1%	1.6%	1.1%	1.5%	1.5%	0.7%	0.6%	---
May-18	3.0%	1.7%	1.9%	2.2%	1.7%	0.6%	2.7%	2.1%	1.8%	1.3%	1.9%	1.8%	0.5%	0.7%	---
Jun-18	2.9%	1.5%	1.3%	1.4%	1.4%	0.2%	2.7%	2.0%	1.6%	1.1%	1.4%	1.5%	0.7%	0.7%	---
Jul-18	3.0%	1.0%	1.1%	1.5%	1.3%	-0.2%	2.3%	1.9%	1.4%	0.9%	1.1%	1.5%	0.8%	1.1%	---
Aug-18	3.1%	1.4%	1.6%	2.0%	1.5%	0.2%	2.1%	1.8%	1.6%	1.0%	1.0%	1.5%	1.2%	1.0%	---
Sep-18	2.8%	1.3%	1.5%	2.1%	1.6%	0.6%	2.3%	2.1%	1.7%	1.1%	1.2%	1.5%	1.2%	1.3%	-0.1%
Oct-18	2.6%	1.7%	1.7%	2.5%	1.7%	1.1%	2.2%	1.7%	1.7%	1.2%	1.5%	1.5%	1.7%	1.0%	0.4%
Nov-18	2.5%	1.5%	1.1%	2.6%	1.5%	1.4%	1.6%	1.5%	1.6%	1.0%	1.0%	1.4%	1.5%	0.9%	0.5%
Dec-18	2.3%	1.6%	1.2%	1.9%	1.6%	1.3%	1.4%	1.3%	1.5%	1.0%	1.0%	1.2%	1.4%	0.9%	0.7%
Avg.*	**2.7%**	**1.5%**	**1.4%**	**2.2%**	**1.6%**	**0.7%**	**2.1%**	**1.8%**	**1.5%**	**1.1%**	**1.2%**	**1.3%**	**1.1%**	**0.9%**	**0.4%**

*Positive values indicate a real savings rate, negative values indicate a negative savings rate (greater usage by treatment customers than control customers).

The Beta wave has been in the field since July 2011 and is the only wave that targets customers in the highest quartile of energy usage in selected baseline territories. It is the first wave of PG&E's HER program, and at 732 kWh, these recipients have the highest average monthly control load of any wave. The Beta wave's average monthly savings rate of 2.7%, and a peak savings of 3.1% in August, combined with the high monthly control load, results in markedly higher per-household electric savings than any other wave. Higher savings rates can be observed in summer months and comparatively lower savings in the winter months, but these are not statistically significant. Other waves display similar seasonal fluctuations in savings as well: for example, the few electric-only waves provide greater savings in the fall and winter than in spring and summer, suggesting that much of the savings come from changes in heating- and cooling-related behavior.

The Gamma wave is the only wave that targets customers in all quartiles of energy use. The Gamma wave comprises three separate experiments, the first being dual-fuel customers and "standard report frequency," the second being dual-fuel customers and "reduced report frequency," and the third being electric-only customers (who receive reports in the standard cadence), and was launched altogether in November 2011. This stratification allows for a comparison of the impact of HER delivery frequency on energy savings as well as the effect of HERs on customers with different fuel types delivered by PG&E.[9] The difference in savings between customers who receive standard-frequency reports (every other month) and those who receive reduced-frequency reports (every three months) is small, with the standard-frequency customers producing an average monthly savings of 1.5% and the reduced-frequency customers producing an average monthly savings of 1.4%. To reiterate, the incremental gain in savings associated with delivering the reports every other month instead of quarterly is statistically insignificant.

Beginning with Wave One, the typical sample frame for PG&E's HER program was dual-fuel customers in the top three quartiles of energy use throughout the service territory. Wave One, launched in March 2012, is two separate experiments: one with dual-fuel customers and one with electric-only customers. Dual-fuel customers saved 1.6% of monthly energy use on average in 2018, while electric-only customers saved 0.7%. This difference in average savings rates is due in large part to very low savings rates observed in the summer months among electric-only customers. The difference in savings rates between dual-fuel and electric-only customers is not statistically significant due to the small sample of electric-only customers included in the wave.

Wave Two is two separate experiments as well: Area 7 and Non-Area 7 of PG&E's service territory, each with its own control group. Customers in Area 7 are located in the northernmost portion of the PG&E service territory (i.e., Humboldt, Mendocino, Lake, and Sonoma counties, primarily). Initially conceived as a single wave comprising the entire service territory with the exclusion of Area 7, PG&E management determined to include Area 7 just prior to the launch of this wave, and so these customers were added relatively late in the process as a separate experiment. Both groups of Wave Two customers have been receiving reports since February

[9] Some electric-only customers have only electricity, while others receive propane from a different supplier.

2013 and had energy savings of 2.1% and 1.8% for Non-Area 7 and Area 7, respectively, in 2018.

Waves Three, Four, Six and Seven share many characteristics. They are comprised of large groups of dual-fuel customers in the top three quartiles of energy use residing throughout PG&E's service territory. These waves had similar electric reference loads in 2018.

- Wave Three customers have been receiving reports since July 2013. In 2018 they provided average monthly savings of 1.5%. The highest savings achieved by these customers was in May 2018, with a savings of 1.8%.

- Wave Four customers began receiving reports in March 2014. In 2018 they provided average monthly savings of 1.1%, with peak savings of 1.3% in May.

- Wave Six customers began receiving reports about one year later (September 2015). Their average monthly savings in 2018 were 1.3%, with peak savings of 1.8% in May.

- Wave Seven customers began receiving reports in March 2017. The average monthly savings in 2018 for this wave was 1.1%, with the highest savings occurring in October, at a peak of 1.7%.

Wave Five, launched in October of 2014, was comprised of dual-fuel customers in the top half of energy use. Given the sample composition, it is not surprising that the monthly electric reference load in 2018 of 675 kWh was substantially higher than most HER waves. Average monthly savings in 2018 were 1.2%, with peak savings of 1.9% in May.

Wave Eight customers began receiving reports in November 2017. Like other waves launched before it, one goal of this wave was to maintain an average number of customers in treatment to counteract the shrinkage due to normal attrition due to customer move-outs. The proportion of qualifying customers had been reduced by several factors (including restrictions on qualifying rates, customers with rooftop solar and electric vehicles), and this resulted in the need to broaden the sample frame to include customers with lower average energy use to meet sample size targets. This wave includes customers in all but the lowest sixteenth of energy use, resulting in the lowest 2018 monthly reference load of 217 kWh—less than half the average per-household energy use of any HER wave. The average savings for this wave was 0.9%.

The most recently-launched wave included in this analysis is Wave Nine. This cohort of customers began receiving reports in September 2018, and for this reason, analysis for this wave only contained the months of September through December. The average monthly savings for this wave was 0.4%, with the highest savings occurring in December with a peak of 0.7%.

While percentage savings estimates provide context for understanding the relative magnitude of the impact of receiving HERs on a customer's energy usage, the average monthly savings in kWh allows for comparisons of actual energy savings between customers in different waves.

Table 2-6 displays the average monthly savings and average savings by month, both expressed in kWh.[10] Specifically:

- As shown in Table 2-5, Beta treatment customers save at least 20% more energy than customers in other waves, on a percentage basis. When comparing the average per-customer kWh saved within each wave in Table 2-6, the Beta group saves at least 70% more energy than any other group on a per-customer basis. This is expected and is the result of higher average energy consumption compared to other groups: Beta customers are in the highest quartile of energy consumption (see Table 1-1). Given their higher energy use, an equal percentage shift in energy use translates to a higher kWh impact. Other waves contribute more total savings to the HER program, however. The number of treated customers in the Beta group, initially 60,000 at its launch in 2011 (see Table 1-1), had been reduced by nearly half by 2018 (see Table 2-3) to 36,512.

- In terms of energy impact, the Gamma "standard frequency" HER recipients saved, on average, about 0.7 kWh extra per month when compared to the Gamma "reduced frequency" HER recipients. These groups saved, respectively, 8.0 kWh and 7.3 kWh. The Gamma electric-only customers outpaced both of the Gamma dual-fuel groups, saving an average of 11.5 kWh per month.

- Wave One electric-only customers provided their greatest kWh savings in the winter and fall, which is the same pattern that appears for the Gamma electric-only wave. This seasonal effect is most likely due to increases in electric heating during the cooler months.

[10] Because the yearly energy usage profile of each wave varies, comparisons using energy savings in terms of percentage and kWh may not show the same patterns across months.

Table 2-6: Average per Customer Impact on Electricity Usage by Wave (kWh)

Month	Beta	Gamma			Wave One		Wave Two		Wave Three	Wave Four	Wave Five	Wave Six	Wave Seven	Wave Eight	Wave Nine
		Dual		Electric-Only	Dual	Electric-Only	Not Area 7	Area 7							
		Standard	Reduced												
Jan-18	18.0	8.5	6.6	14.5	8.0	5.7	7.0	8.0	7.3	4.9	5.9	3.7	5.2	2.3	---
Feb-18	18.0	8.5	4.9	15.4	8.9	8.5	8.2	8.3	7.3	4.8	7.3	4.2	6.9	1.9	---
Mar-18	16.0	7.6	6.0	11.6	7.4	6.8	8.6	9.3	6.7	3.7	5.8	4.4	5.4	1.4	---
Apr-18	17.3	7.3	7.7	11.2	7.6	4.2	10.4	8.7	6.7	4.1	7.7	6.0	3.2	1.2	---
May-18	18.5	6.9	8.0	8.8	7.2	2.5	11.3	8.3	7.5	5.1	10.2	7.6	2.3	1.3	---
Jun-18	21.8	9.3	7.8	7.4	8.0	1.7	14.0	8.8	8.2	5.5	10.9	7.7	3.9	1.6	---
Jul-18	27.1	8.5	8.9	10.9	9.0	-2.4	15.0	8.8	8.7	5.7	11.0	9.5	5.9	2.7	---
Aug-18	24.2	10.1	11.5	13.2	9.4	2.2	12.4	7.8	9.1	5.3	8.6	8.6	7.3	2.3	---
Sep-18	18.9	6.7	7.9	10.5	8.1	3.7	10.9	8.7	8.4	5.0	7.7	7.1	6.4	2.6	-0.7
Oct-18	17.0	7.1	6.9	10.6	7.6	4.9	9.5	7.3	7.5	5.0	8.2	6.5	7.5	2.0	2.2
Nov-18	19.1	6.9	5.0	13.4	7.7	7.1	8.1	7.6	7.8	4.6	6.0	6.5	7.7	2.0	3.3
Dec-18	20.0	8.4	6.0	11.3	9.0	7.3	7.6	7.2	8.0	5.1	7.1	6.2	7.9	2.3	4.6
Avg.*	**19.6**	**8.0**	**7.3**	**11.5**	**8.1**	**4.3**	**10.3**	**8.2**	**7.7**	**4.9**	**8.0**	**6.5**	**5.7**	**1.9**	**2.3**

*Positive values indicate a real savings rate, negative values indicate a negative savings rate (greater usage by treatment customers than control customers).

2.3 Gas Savings Observed by Month

As with the electricity savings analysis, gas savings were assessed on a per-month and yearly average basis in terms of both the average percentage impact and the average raw energy consumption impact. For each wave, the therm impact is below the yearly average in the summer months and above the yearly average in the winter months. This is because more gas is used in the winter for heating, which allows for larger potential reductions. Additionally, because small changes in gas use result in larger percentage impacts in the summer months, all waves show large fluctuations in percentage impact during the summer and relatively small fluctuations in percentage impact in the winter. Table 2-7 presents the average percentage impact by month and the average monthly impact through the end of 2018.

Table 2-7: Average Percentage Impact on Gas Usage by Wave

Month	Beta	Gamma		Wave One	Wave Two		Wave Three	Wave Four	Wave Five	Wave Six	Wave Seven	Wave Eight	Wave Nine
		Dual		Dual	Not Area 7	Area 7							
		Standard	Reduced										
Jan-18	1.1%	0.7%	0.6%	0.7%	0.9%	1.0%	0.8%	0.8%	0.6%	0.4%	0.4%	0.5%	---
Feb-18	1.1%	0.6%	0.7%	0.9%	0.8%	0.9%	1.0%	0.4%	0.9%	0.4%	0.7%	0.3%	---
Mar-18	1.3%	0.5%	0.6%	0.7%	1.1%	0.9%	1.1%	0.3%	0.8%	0.4%	0.8%	0.5%	---
Apr-18	1.4%	0.9%	0.8%	1.1%	1.2%	1.5%	1.2%	0.6%	1.1%	0.8%	0.7%	1.0%	---
May-18	0.9%	1.0%	0.7%	1.1%	1.2%	1.8%	0.9%	1.1%	0.4%	1.1%	0.7%	0.4%	---
Jun-18	1.2%	1.0%	0.3%	1.3%	0.9%	1.6%	1.4%	1.0%	0.4%	0.9%	0.6%	0.4%	---
Jul-18	1.2%	0.9%	0.1%	1.1%	0.8%	1.3%	0.7%	1.0%	0.8%	0.5%	0.5%	0.5%	---
Aug-18	0.8%	0.6%	0.6%	1.2%	1.0%	1.4%	1.2%	0.9%	0.9%	0.4%	0.9%	0.5%	---
Sep-18	0.8%	1.2%	0.7%	1.3%	0.8%	2.3%	1.2%	1.4%	0.2%	0.7%	1.0%	0.9%	0.6%
Oct-18	0.3%	1.2%	1.0%	1.2%	1.1%	1.9%	1.0%	1.4%	0.5%	0.6%	0.5%	1.3%	0.9%
Nov-18	1.2%	0.7%	0.4%	1.1%	0.9%	1.0%	0.9%	0.8%	0.4%	0.7%	0.5%	1.6%	0.7%
Dec-18	1.3%	0.5%	0.4%	0.9%	0.8%	0.9%	0.8%	0.9%	0.4%	0.9%	0.5%	1.4%	0.5%
Avg.*	**1.1%**	**0.7%**	**0.6%**	**1.0%**	**0.9%**	**1.2%**	**1.0%**	**0.8%**	**0.6%**	**0.6%**	**0.6%**	**0.8%**	**0.7%**

*Positive values indicate a real savings rate, negative values indicate a negative savings rate (greater usage by treatment customers than control customers).

Except for Wave Nine, which only contains data for four cooler months, percentage gas savings are lower than percentage electric savings for every wave. Table 2-8 shows the average gas usage impact in therms on a per-customer basis.

Table 2-8: Average per Customer Impact on Gas Usage by Wave (Therms)

Month	Beta	Gamma		Wave One	Wave Two		Wave Three	Wave Four	Wave Five	Wave Six	Wave Seven	Wave Eight	Wave Nine
		Dual		Dual	Not Area 7	Area 7							
		Standard	Reduced										
Jan-18	1.08	0.44	0.38	0.40	0.53	0.67	0.47	0.42	0.43	0.20	0.25	0.18	---
Feb-18	1.17	0.36	0.42	0.56	0.50	0.62	0.61	0.24	0.63	0.24	0.39	0.08	---
Mar-18	1.10	0.22	0.30	0.34	0.54	0.54	0.55	0.14	0.46	0.20	0.38	0.15	---
Apr-18	0.75	0.26	0.22	0.34	0.37	0.54	0.38	0.17	0.38	0.25	0.23	0.19	---
May-18	0.33	0.19	0.13	0.24	0.27	0.44	0.21	0.24	0.10	0.23	0.15	0.07	---
Jun-18	0.31	0.15	0.05	0.21	0.17	0.29	0.26	0.18	0.07	0.16	0.10	0.06	---
Jul-18	0.25	0.12	0.01	0.16	0.14	0.21	0.12	0.16	0.13	0.08	0.08	0.06	---
Aug-18	0.19	0.09	0.08	0.18	0.17	0.24	0.22	0.15	0.15	0.07	0.16	0.07	---
Sep-18	0.20	0.18	0.12	0.21	0.14	0.42	0.22	0.24	0.04	0.12	0.18	0.11	0.10
Oct-18	0.09	0.23	0.19	0.25	0.24	0.47	0.23	0.30	0.11	0.14	0.10	0.18	0.22
Nov-18	0.98	0.31	0.17	0.53	0.43	0.51	0.44	0.36	0.21	0.29	0.21	0.41	0.34
Dec-18	1.52	0.33	0.25	0.59	0.51	0.63	0.48	0.50	0.32	0.53	0.29	0.48	0.37
Avg.*	**0.66**	**0.24**	**0.19**	**0.33**	**0.33**	**0.46**	**0.35**	**0.26**	**0.25**	**0.21**	**0.21**	**0.17**	**0.26**

*Positive values indicate a real savings rate, negative values indicate a negative savings rate (greater usage by treatment customers than control customers).

The Beta wave customers show the highest therm savings with an average of 0.66 therms saved per customer per month, which is expected given the Beta wave customers' higher energy use. Not counting Wave Nine, which does not include several winter months, Wave Eight provided the least savings at 0.17 therms saved per customer per month. This low result is primarily driven by the low savings in January through March 2018, which had lower savings than nearly every other wave.

3 Demand Savings

The deployment of Smart Meter technology has enabled PG&E to collect electric usage data at one-hour intervals (interval data) for residential customers throughout its service territory.[11] This granularity of data provides the means to estimate reductions in usage attributable to the HER program for specific hours throughout the day. This section documents the demand savings of PG&E's Home Energy Reports program calculated using hourly interval data obtained from PG&E's Smart Meter system for 2018. In this section we:

- Define Peak Megawatt Load Reduction (PMLR), as provided in the Database for Energy Efficiency Resources (DEER, see http://deeresources.com/), since it is used as a basis for the HER demand savings claim;
- Describe the methodology used to estimate PMLR for HER using interval data; and
- Apply the methodology to estimate PMLR for summer 2018 to include in the HER savings claims.

Peak Megawatt Load Reduction (PMLR): The PMLR is the difference between the electricity demand of HER-treated households and their expected demand in the absence of treatment during specific peak weather conditions. In this analysis, the peak periods are identified using the DEER definition of weather conditions that are expected to produce a regional grid peak event. These peaks comprise the hours of 2 PM to 5 PM during a "heat wave," which is defined as three consecutive weekdays of especially warm weather conditions. A single extreme heat wave for the year is also identified for the PG&E territory. This particular heat wave is defined as being the period that contains the three consecutive weekdays for which the average daily temperature, plus the average temperature between 12 PM and 6 PM, plus the maximum daily temperature, is greater than that same sum for all other consecutive three-weekday intervals throughout the year. Demand savings are also reported for the CAISO and PG&E system peak hours.

Methodology for Calculating PMLR for Home Energy Reports: For the evaluation of Home Energy Reports (HERs), aggregate peak demand reductions are defined as the difference between an aggregate reference load (from the HER control group) and the aggregate treatment group's average demand during the hours of 2 to 5 PM on the 2018 heat wave, minus the difference between the same groups during the hours of 2 to 5 PM on the heat wave from the year prior to the onset of treatment. This procedure produces what is known as a "difference-in-differences" estimate. Demand savings are estimated separately for each experimental wave. Calculating the PMLR involves several steps:

1. Collect 60-minute kWh interval data from all PG&E residential customer households in the treatment and control groups for each HER experiment in the field.

[11] The system captures usage data at more frequent intervals, but only hourly interval data is stored for most PG&E residential customers.

   a. This data is collected for the days and hours comprising the "heat wave," defined using DEER's definition of a three-day heat wave for the calendar year of interest.
   b. Data is also collected for the CAISO and PG&E system peak hours.[12]
   c. Lastly, data is collected from the summer prior to the onset of treatment so that pre-existing differences between treatment and control groups can be determined.
2. For each experimental wave, calculate the average per-household hourly impact as the difference between the average control and treatment demands over the 2018 peak period, minus the difference between the average control and treatment demands over the peak period in the 12 months prior to the experimental wave's launch date.
3. Report the aggregate kW impact contained in the "heat wave" date range and CAISO and PG&E system peak hours for each experimental wave.

Calculation of Peak Megawatt Load Reduction for 2018: Using DEER's definition of a three-day heat wave, peak periods in 2018 were estimated for PG&E's territory using weather data provided by PG&E. This weather data consists of hourly temperature values for each weather station within PG&E's territory. Because there are multiple weather stations within the territory, a weighted average of weather station temperatures was used to estimate the hourly temperatures at the territory level. The weights in this calculation are the number of residential PG&E customers residing in each weather station's area.

According to the DEER criteria, three-day peak periods must be non-holiday weekdays falling between June 1 and September 30. The heat wave for each year will have the highest sum of the average temperature over the three consecutive weekdays, the average temperature from noon to 6 PM over the three days, and the peak temperature during the three days. Further details of DEER's definition can be found by accessing the CPUC Energy Efficiency Policy Manual.[13]

Although customers will experience multiple heat waves throughout the summer, the DEER criteria are used to select a single, maximum heat wave. The goal of using these criteria is to estimate the heat wave that had the largest impact on the system as a whole. Based on the data obtained for the current analysis, the 2018 maximum heat wave was identified to have occurred from Monday, July 9, 2018 to Wednesday, July 11, 2018.

To calculate the demand savings for the heat wave and for the PG&E and CAISO system peaks, 60-minute interval data were collected for each treatment and control customer within each of 14 experimental HER waves in the field over the summer of 2018.[14]

[12] See Appendix A for savings estimates during the CAISO and PG&E system peak hours

[13] https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/EEPolicyManualV5forPDF.pdf

[14] Wave Two consists of two separate experiments with unique control groups for PG&E Service Territory Area 7 (known as North Coast and comprises Humboldt, Mendocino, and Lake counties, as well as most of Sonoma County and portions of Marin County) and for the remainder of the service territory. The Gamma Wave and Wave One each have separate treatment and control groups for dual-fuel and all-electric experiments. Wave Nine was launched after the summer of 2018 and is not included in the heat wave or peak demand savings calculations. The result is 14 unique experiments with summer data available for 2018.

In order to account for pre-existing differences in peak load consumption, peak demand savings were calculated for each experimental wave using a difference-in-differences approach that incorporated data from the current year (2018) as well as from the summer prior to that wave's launch date. Because the goal is to compare usage behavior during peak periods, Nexant identified the summer peaks for 2011 through 2018 (using the DEER definition of the annual peak period and data from PG&E's weather stations) and made year-to-year comparisons using data from each year's peak period. For each experimental wave, the average electric demand from 2 to 5 PM was calculated separately for the treatment and control customers. The average per-household demand reduction was then estimated as the difference between the average control and treatment usages across these hours.

Table 3-1 on the following page shows the pre- and post-treatment demands and differences for each wave. The pre-treatment difference between the average treatment and control demand from 2 to 5 PM is 0.01 kW or less for each experimental wave.

Table 3-1: Differences between Treatment and Control Peak Demand During Pre-Treatment and Post-Treatment Periods*

Experimental Wave	Treatment Period	Heatwave Start	Heatwave End	Avg. Control Demand 2-5 PM (kW)	Avg. Treatment Demand 2-5 PM (kW)	Difference (kW)	95% Confidence Interval	
Beta - Jul. 2011	Pre Treatment	20-Jun-11	22-Jun-11	2.81	2.81	0.00	-0.02	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.82	1.77	0.05	0.02	0.08
Gamma Standard - Nov. 2011	Pre Treatment	20-Jun-11	22-Jun-11	1.98	1.98	0.00	-0.02	0.01
	Post Treatment	9-Jul-18	11-Jul-18	1.49	1.48	0.01	-0.01	0.03
Gamma Electric - Nov. 2011	Pre Treatment	20-Jun-11	22-Jun-11	1.62	1.62	0.00	-0.02	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.33	1.31	0.02	-0.01	0.05
Gamma Reduced - Nov. 2011	Pre Treatment	20-Jun-11	22-Jun-11	1.98	1.97	0.01	-0.01	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.49	1.48	0.01	-0.01	0.03
Wave One - Feb. 2012	Pre Treatment	20-Jun-11	22-Jun-11	1.78	1.77	0.01	0.00	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.32	1.31	0.02	0.00	0.03
Wave One Electric - Feb. 2012	Pre Treatment	20-Jun-11	22-Jun-11	2.13	2.13	-0.01	-0.04	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.70	1.71	-0.01	-0.06	0.05
Wave Two - Area 7 - Feb 2013	Pre Treatment	8-Aug-12	10-Aug-12	0.95	0.95	0.00	-0.01	0.01
	Post Treatment	9-Jul-18	11-Jul-18	0.82	0.79	0.02	0.01	0.04
Wave Two - Not Area 7 - Feb. 2013	Pre Treatment	8-Aug-12	10-Aug-12	1.48	1.48	0.00	-0.01	0.01
	Post Treatment	9-Jul-18	11-Jul-18	1.16	1.12	0.04	0.02	0.06
Wave Three - Jul. 2013	Pre Treatment	8-Aug-12	10-Aug-12	1.42	1.42	0.00	-0.01	0.01
	Post Treatment	9-Jul-18	11-Jul-18	1.15	1.14	0.01	0.00	0.03
Wave Four - Mar. 2014	Pre Treatment	1-Jul-13	3-Jul-13	1.63	1.62	0.01	0.00	0.02
	Post Treatment	9-Jul-18	11-Jul-18	1.11	1.10	0.01	0.00	0.03
Wave Five - Oct. 2014	Pre Treatment	23-Jul-14	25-Jul-14	2.09	2.10	-0.01	-0.02	0.00
	Post Treatment	9-Jul-18	11-Jul-18	1.92	1.90	0.02	0.00	0.04
Wave Six - Sept. 2015	Pre Treatment	23-Jul-14	25-Jul-14	1.11	1.11	0.00	-0.01	0.01
	Post Treatment	9-Jul-18	11-Jul-18	1.20	1.17	0.04	0.02	0.05
Wave Seven – Mar. 2017	Pre Treatment	26-Jul-16	28-Jul-16	1.67	1.68	0.00	-0.01	0.01
	Post Treatment	9-Jul-18	11-Jul-18	1.35	1.35	0.00	-0.02	0.02
Wave Eight – Nov. 2017	Pre Treatment	30-Aug-17	1-Sep-17	0.43	0.43	0.00	0.00	0.01
	Post Treatment	9-Jul-18	11-Jul-18	0.40	0.39	0.01	0.00	0.01

* Rounding may make these small numbers misleading

Table 3-2 on the following page presents the demand reductions for the peak heat wave period of July 9 through July 11 using difference-in-differences estimation. Customers experienced temperatures around 87 degrees Fahrenheit during this period. The aggregate peak reduction in 2018, before adjusting for joint savings, is estimated to be 27.2 MW, which is significantly greater than the reduction of 18.1 MW estimated for 2017. There are two possible explanations for this increase. First, there was a rise in the per-household electric energy impact from HERs in most waves, with the exceptions of the electric-only Gamma wave and Waves One, Five, and Seven. Second, the average temperature during the peak period in 2018 was cooler (87 degrees Fahrenheit versus 2017's average of 94 degrees) which may have led to customers to be more willing to reduce air conditioning use in 2018.

Customers in the Beta wave provided the greatest reductions in peak load of 0.05 kW per customer, on average. This is not surprising given that the Beta wave includes higher energy users and has been in the field for the longest period. Customers in the Beta wave, both Wave Two groups, and Wave Six had statistically significant percent impacts over 3%. All other waves did not have statistically significant demand reductions. The lack of statistically significant reductions across all Gamma waves could be explained by their composition: these are the only HER waves that include customers in the lowest quartile of energy usage, which means there are more customers in these waves that have fewer opportunities to reduce their electric usage. The Gamma waves also did not produce significant results for PMLR in 2015, 2016, or 2017.

Table 3-2: Peak Heat Wave Demand Reductions by Experimental Wave

Wave	Number of Control Residences	Number of Treated Residences	Control Load (kW)	Treatment Load (kW)	Impact (kW)	Percent Impact	95% Confidence Interval		Aggregate Impact (MW)	Temperature (F)
Beta	37,799	37,573	1.82	1.77	0.05	3.0%	0.02	0.09	2.0	89
Gamma	43,161	43,151	1.49	1.48	0.01	0.8%	-0.01	0.04	0.5	92
Gamma Electric	20,417	20,371	1.33	1.31	0.02	1.6%	-0.01	0.06	0.4	93
Gamma Reduced	43,161	43,005	1.49	1.48	0.00	0.3%	-0.02	0.03	0.2	92
Wave 1	56,165	224,303	1.32	1.31	0.00	0.3%	-0.01	0.02	1.0	88
Wave 1 Electric	5,108	20,210	1.70	1.71	0.00	0.1%	-0.06	0.06	0.0	94
Wave 2 Area 7	32,622	52,296	0.82	0.79	0.03	3.4%	0.01	0.04	1.5	87
Wave 2 Not Area 7	32,046	205,093	1.16	1.12	0.04	3.4%	0.02	0.06	8.1	85
Wave 3	45,200	135,850	1.15	1.14	0.01	1.0%	-0.01	0.03	1.6	86
Wave 4	42,487	113,101	1.11	1.10	0.01	0.5%	-0.01	0.02	0.7	86
Wave 5	31,978	134,187	1.92	1.90	0.03	1.3%	0.00	0.05	3.4	93
Wave 6	31,214	194,831	1.20	1.17	0.04	3.0%	0.02	0.05	7.1	87
Wave 7	29,338	115,307	1.35	1.35	0.00	0.3%	-0.02	0.03	0.5	88
Wave 8	19,895	129,204	0.40	0.39	0.00	0.5%	-0.01	0.01	0.3	81
Average/Total	470,591	1,468,482	1.24	1.22	0.02	1.5%	0.01	0.02	27.2	87

Similar to the process used to deduct the joint kWh and therm savings resulting from PG&E's downstream energy efficiency programs, the overlap with demand savings for all measures installed under downstream PG&E programs was estimated for both treatment and control group members using data contained in the PG&E MDSS system. The double-counted demand savings were obtained by subtracting the control group downstream savings from the treatment group downstream savings for each measure.

The overlap in demand savings with PG&E's Upstream Lighting Program was estimated using Equation 3. This is similar to the approach used to estimate joint energy savings described in Section 2. Additional information regarding the inputs and sources can be found in Appendix A.

Equation 3: Joint Peak Demand Savings Estimate

$$\begin{aligned} &Additional\ kW\ savings\ attributable\ to\ ULP \\ &= kW\ savings\ per\ bulb\ \times additional\ bulbs\ per\ treatment\ customer \\ &\times percent\ of\ bulbs\ installed\ during\ 2018\ peak \\ &\times percent\ of\ bulb\ sales\ that\ received\ rebates\ \times \frac{delta\ watts}{1000} \\ &\times peak\ coincidence\ factor \times NTG \end{aligned}$$

The downstream adjustment to the aggregate demand reduction was estimated to be 0.2 MW, and the upstream adjustment was estimated to be 0.4 MW. After these adjustments for joint savings, the peak load reduction for the HER program is 26.6 MW. The aggregate demand impacts for the CAISO and PG&E system load peaks can be founded in Appendix B.

4 Persistence Study

PG&E's HER Persistence Study was launched in May 2014. The objective of the study is to understand how long the savings effects of the treatment endure after it is stopped. Customers in the Gamma Dual Standard and Gamma Dual Reduced experimental waves were randomly assigned to "continued" and "terminated" groups, the second of which did not receive any reports after the launch of the persistence study, which began two and a half years following the onset of the treatment. Between the two waves, a total of 28,000 customers were assigned to stop receiving treatment: 14,000 from the Gamma Dual Standard wave and 14,000 from Gamma Dual Reduced wave. Gamma Standard customers had received the reports every two months while Gamma Reduced customers had received the reports quarterly. Both waves were launched in November 2011.

The methodology for estimating HER persistence is identical to that used for measuring the program energy savings with one key difference: rather than using pre-treatment and post-treatment periods, the persistence model uses pre-termination and post-termination periods. The pre-termination period is defined to be the full year prior to the launch of the persistence study. Additionally, "treatment" in this context is defined as the termination of receiving reports. The following model, with terms described in Table 4-1, measures the difference in energy savings between the continued and terminated groups.

Equation 4: Regression Specification

$$kWh_{it} = a + b_t + c_t \cdot termination_i + d \cdot pre\_termination\_kwh_{it} + e_t \cdot pre\_termination\_kwh_{it} + \varepsilon_{it}$$

Table 4-1: Lagged Dependent Variable Model Definitions

Variable	Definition
kWh_{it}	Customer *i*'s usage in season or year *t*
a	The energy consumption constant
b_t	The coefficient for the year-season or year indicator variable
c_t	The coefficient for the year-season or year indicator variable for terminated customers. This is the persistence effect for the particular season or year *t*
$termination_i$	Termination indicator variable for customer *i*. Equal to 1 for terminated customers and 0 otherwise
d	The coefficient for pre-termination consumption
e_t	The coefficient on pre-termination consumption for a particular season or year *t*
$pre\_termination\_kwh_{it}$	Pre-termination energy usage for customer *i* for season or year *t*. Pre-termination consumption for a particular season in the post termination period refers to the same season in the pre-termination period
ε_{it}	The error term

The four figures and associated tables in the following section present electric energy savings estimates for customers with treatment withdrawn (terminated) and those who continued receiving reports, for each year of the study, for each of the two experimental waves. The values presented in the "Savings Reduction for Terminated Group" column were derived using the model described at the start of this section. The savings estimates for continued customers were derived using the model described in Section 2 with the limitation that only customers who were active at the time of random assignment to the terminated and continued groups were included. As a result, the energy savings presented here differ slightly from those presented in the earlier sections.

4.1 Persistence of Electricity Savings

This section summarizes the persistence of electric energy savings for the Gamma Standard and Gamma Reduced experimental waves for each successive season of the experiment. The figures in this section and the following section provide the clearest illustration of how HER impacts persist after cessation of treatment. The figures present the percent of electric energy savings that persist across the first five years of the study for each experimental wave, with each year being the period from May to April of the following calendar year (i.e., Year 1 includes the months from May 2014 through April 2015). By estimating persistence on an annual and seasonal level we are able to observe long-term trends in the data that may be obfuscated by more granular, month-to-month variations. The y-axis represents the percent of the continued group savings that the terminated group achieved (i.e., a persistence of 80% indicates that the energy savings of the terminated group is estimated to be 80% of the energy savings of the continued group). The 90% confidence interval of the estimate is included as dashed lines in the figure. For the Gamma Standard experimental wave, there is an apparent downward trend in electric energy savings of the terminated customers relative to the customers who continue to receive HERs.

- In the first year of the study, the difference in savings rates between the continued and terminated groups was about 18%. In other words, savings from customers who had been withdrawn from treatment dropped by an average of around 18% over the first year. However, this difference was not statistically significant, indicating that savings persisted during the first year.

- The savings decay increased to about 32% in the second. In other words, about one third of the savings produced by HER was lost within two years following the withdrawal of the reports – however this decay was not statistically significant at the 90% confidence level.

- The savings decay increased in the third year to 68. In other words, about two thirds of the savings produced by HER was lost within three years following the withdrawal of the reports. This was the first year to show statistically significant differences in savings between the continued and discontinued groups, meaning the savings from HERs persisted for approximately two years after the discontinuation of treatment.

- The savings decay decreased to 53% in the fourth year and increased to 69% in the fifth year. The fourth and fifth year differences in energy savings between the continued and discontinued groups were statistically significant.

It is important to bear in mind that, although the difference in savings between the continued and terminated groups appears substantial and is statistically significant for three of the years, the magnitude of the change in savings cannot be precisely estimated. This stems from the low statistical power in the test that was conducted. For the 2018 analysis year, the impact on annual electricity usage of the Gamma Standard treatment group is approximately 1.5% (see Table 2-5). This is a relatively small change in usage that requires a relatively large sample size (i.e., in excess of 10,000) to reliably detect. Removing treatment from 14,000 customers for 60 months reduced the treatment effect by about 70%. This large percentage change in the treatment effect represents a small change in annual electricity usage, since it is 70% of the original 1.5% impact – around 1.1%. This very small difference requires a very large sample size to reliably detect. Based on the width of the 90% confidence interval, we can say with 90% confidence that the decay in the treatment effect in the fifth year after removal is in the range of 18% to 120%. Although this is a wide confidence interval, the entire interval shows a positive treatment decay. This, along with viewing the overall trends in Figure 4-1, suggests that the terminated group of the Gamma Standard wave has statistically significant lower electric savings than the continued group after five years.

Table 4-2 presents a seasonal breakdown of the savings and persistence of savings in the Gamma Standard wave. The difference in savings between the continued and terminated customers are statistically significant in every summer from Year 2 onward, indicating that the fall-off in savings in the customers no longer receiving HERs begins in the summer, when customers are likely using more energy to cool their homes.

Figure 4-1: Annual Electric Savings Persistence - Gamma Standard Wave

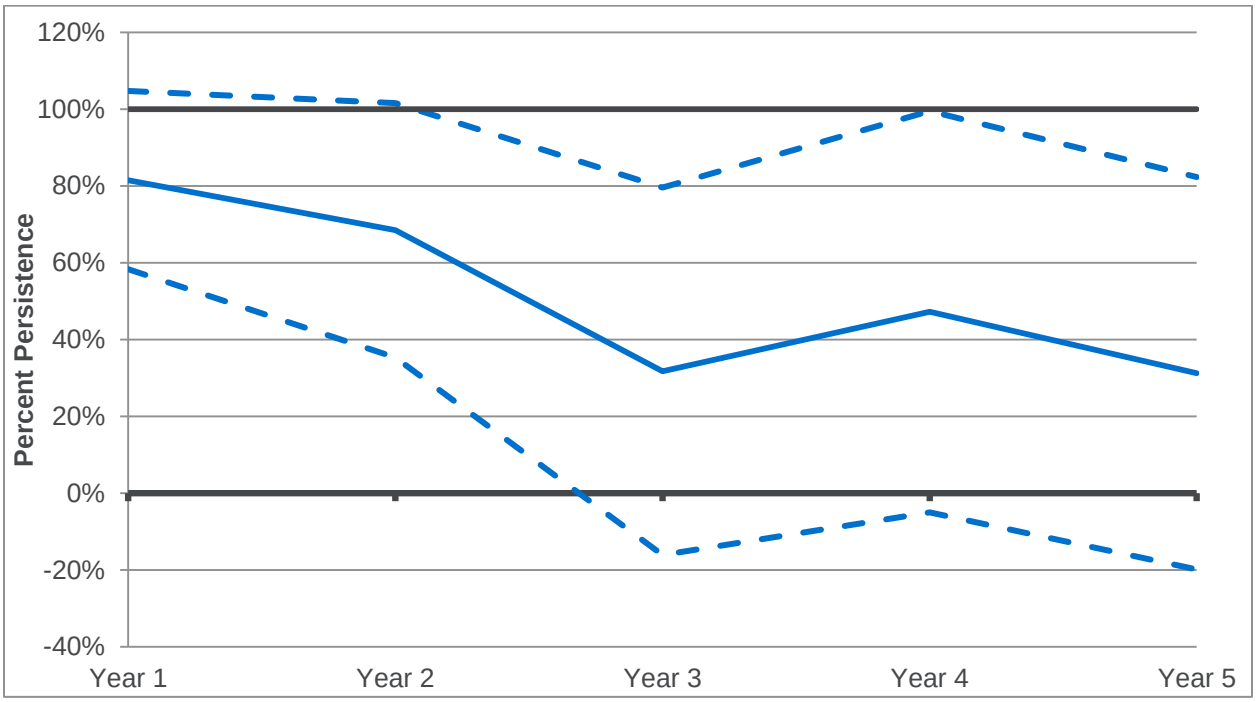

Table 4-2: Seasonal Electric Savings - Gamma Standard Wave

Season	Time Frame	Monthly kWh Savings		Savings Reduction for Terminated Group	Percent Persistence	Percent Persistence 90% Confidence Interval	
		Continued	Terminated				
Spring 1	May 2014	8.3	7.3	1.0	88%	51%	125%
Summer 1	June 2014 - Aug. 2014	12.2	9.1	3.1	75%	45%	104%
Autumn 1	Sept. 2014 - Nov. 2014	9.6	8.6	1.0	89%	61%	118%
Winter 1	Dec. 2014 - Feb. 2015	8.7	6.9	1.8	79%	50%	109%
Spring 2	Mar. 2015 - May 2015	8.1	6.5	1.6	81%	41%	121%
Summer 2	June 2015 - Aug. 2015	12.7	5.7	7.0	45%	8%	83%
Autumn 2	Sept. 2015 - Nov. 2015	10.3	7.1	3.2	69%	35%	104%
Winter 2	Dec. 2015 - Feb. 2016	9.8	8.9	0.9	91%	57%	125%
Spring 3	Mar. 2016 - May 2016	8.3	5.0	3.3	60%	9%	112%
Summer 3	June 2016 - Aug. 2016	12.6	2.0	10.6	16%	-29%	61%
Autumn 3	Sept. 2016 - Nov. 2016	8.4	2.9	5.5	34%	-12%	80%
Winter 3	Dec. 2016 - Feb. 2017	6.7	3.4	3.3	51%	-8%	109%
Spring 4	Mar. 2017 - May 2017	5.1	2.3	2.8	45%	-52%	142%
Summer 4	June 2017 - Aug. 2017	10.8	1.2	9.5	11%	-50%	73%
Autumn 4	Sept. 2017 - Nov. 2017	8.0	5.7	2.4	71%	16%	126%
Winter 4	Dec. 2017 - Feb. 2018	9.1	5.8	3.3	63%	17%	109%
Spring 5	Mar. 2018 - May 2018	8.5	4.3	4.2	51%	-14%	115%
Summer 5	June 2018 - Aug. 2018	11.9	2.8	9.1	23%	-34%	81%
Autumn 5	Sept. 2018 - Nov. 2018	8.3	3.5	4.7	43%	-13%	99%
Winter 5	Dec. 2018 - Feb. 2019	9.5	3.4	6.2	35%	-13%	83%
Spring 6	Mar. 2019 - Apr. 2019	8.8	1.6	7.3	18%	-48%	84%

Figure 4-2 and the accompanying Table 4-3 present the difference in electric savings for the Gamma Reduced wave for each of the five years and for each season of the experiment, respectively. Like the Gamma Standard wave, there is a downward trend in savings year-to-year, however, unlike Gamma Standard wave, none of the years show statistically significant differences between the terminated and continued groups.

On average, customers in the terminated group had larger savings than those in the continued group by about 20% in the first year, 16% in the second year, and 11% in the third year. Starting in the fourth year, the terminated group began to see lower savings than the continued group, with savings 13% smaller in the fourth year and 22% smaller in the fifth year. Much like what was found in the Gamma Standard results, the confidence intervals on these savings impacts are large. In the fifth year, for example, the 90% confidence interval on the savings persistence after terminating HERs ranges from 16% to 139%. In other words, there is no statistically significant difference between the terminated and continued groups for five years after the discontinuation of reports in the terminated group. As mentioned earlier in this section, the persistence study would have benefitted from greater statistical power.

On a seasonal level, as shown in Table 4-3, there are no estimates throughout the five years of the study that show a statistically significant difference between the groups. This includes the summers, which were the first seasons to show differences in the Gamma Standard wave. In summary, the persistence of savings from HERs for the Gamma Reduced wave have persisted for five years, although the year-to-year trend is still downward. If the persistence study is continued in future years, one might expect to start seeing statistically significant differences in the summer.

Figure 4-2: Annual Electric Savings Persistence - Gamma Reduced Wave

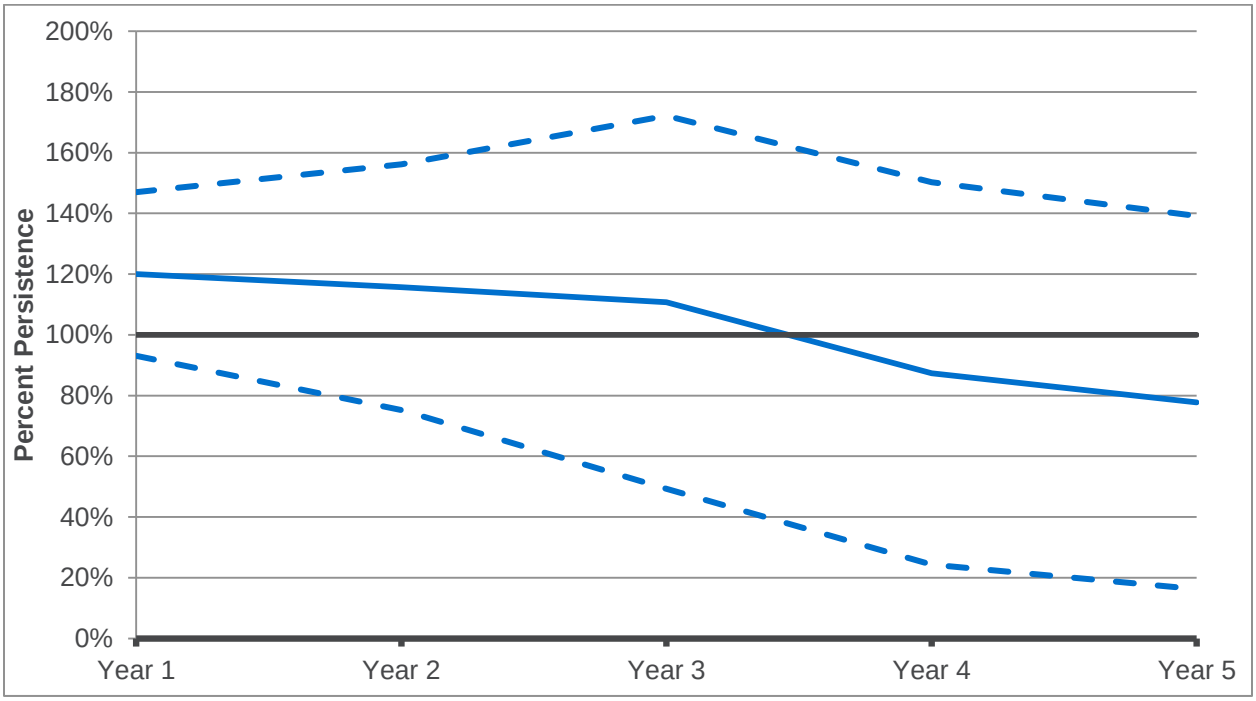

Table 4-3: Seasonal Electric Savings - Gamma Reduced Wave

Season	Time Frame	Monthly kWh Savings		Savings Reduction for Terminated Group	Percent Persistence	Percent Persistence 90% Confidence Interval	
		Continued	Terminated				
Spring 1	May 2014	6.1	8.5	-2.4	140%	88%	192%
Summer 1	June 2014 - Aug. 2014	7.8	12.3	-4.5	157%	114%	201%
Autumn 1	Sept. 2014 - Nov. 2014	7.8	9.0	-1.2	115%	85%	146%
Winter 1	Dec. 2014 - Feb. 2015	7.2	7.0	0.2	97%	67%	128%
Spring 2	Mar. 2015 - May 2015	6.7	6.9	-0.2	102%	61%	144%
Summer 2	June 2015 - Aug. 2015	8.6	11.3	-2.6	130%	79%	181%
Autumn 2	Sept. 2015 - Nov. 2015	7.5	9.7	-2.2	129%	87%	171%
Winter 2	Dec. 2015 - Feb. 2016	6.9	6.1	0.8	88%	44%	133%
Spring 3	Mar. 2016 - May 2016	5.7	6.3	-0.6	111%	45%	177%
Summer 3	June 2016 - Aug. 2016	7.6	10.1	-2.6	134%	64%	204%
Autumn 3	Sept. 2016 - Nov. 2016	5.8	6.8	-1.0	117%	59%	176%
Winter 3	Dec. 2016 - Feb. 2017	5.3	3.8	1.5	72%	8%	137%
Spring 4	Mar. 2017 - May 2017	4.0	3.5	0.5	87%	-22%	195%
Summer 4	June 2017 - Aug. 2017	6.6	6.7	0.0	100%	7%	193%
Autumn 4	Sept. 2017 - Nov. 2017	6.8	6.6	0.2	97%	40%	154%
Winter 4	Dec. 2017 - Feb. 2018	6.5	4.4	2.1	67%	10%	125%
Spring 5	Mar. 2018 - May 2018	7.4	5.9	1.5	80%	11%	149%
Summer 5	June 2018 - Aug. 2018	9.0	10.2	-1.2	113%	40%	187%
Autumn 5	Sept. 2018 - Nov. 2018	7.0	6.2	0.7	90%	29%	150%
Winter 5	Dec. 2018 - Feb. 2019	6.6	2.8	3.8	42%	-24%	107%
Spring 6	Mar. 2019 - Apr. 2019	6.5	2.1	4.4	32%	-52%	117%

4.2 Persistence of Gas Savings

In the electricity section, we observed that the electricity savings decay first became apparent for the Gamma Standard wave in the summer, which is when load is typically highest due to air conditioning usage. For gas energy savings, we would expect a similar trend where the gas savings decay becomes apparent in the winter months.

Figure 4-3 and Table 4-4 show the year-to-year and season-to-season gas savings and persistence, respectively, of the Gamma Standard experimental wave. Unlike in the electric savings results, the difference in savings between the terminated and continued customers is statistically significant in all years, including the first year of the persistence study. From Table 4-4, it is apparent that there are statistically significant differences in savings in every winter (when the most gas is used) and occasionally in the spring or autumn seasons. These results indicate that the customers in the Gamma Standard wave were quick to forget the natural gas-saving habits they had formed, losing approximately 95% of their winter gas savings by the first winter – approximately 7 months after stopping HERs. Additionally, unlike in the electric savings results, Figure 4-3 does not appear to show a year-to-year decline in savings of the terminated group relative to the continued group. The trend is remarkably flat, which could be indicative of a behavioral shift back to that of the control customers, but with the small amount of continued savings from energy-saving technological improvements. In the fifth year, the terminated group had savings of approximately 31% of the continued group savings, with a 90% confidence interval of -24% to 86%.

Figure 4-3: Annual Gas Savings Persistence - Gamma Standard Wave

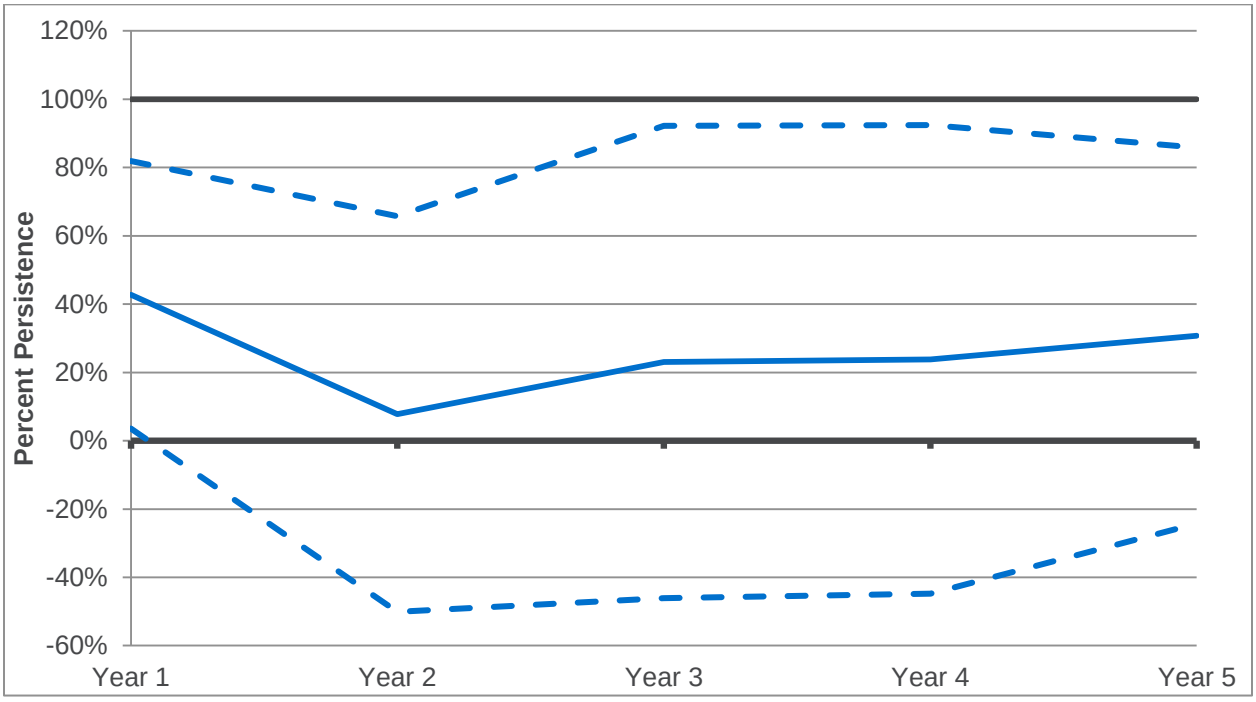

Table 4-4: Seasonal Gas Savings - Gamma Standard Wave

Season	Time Frame	Monthly Therm Savings		Savings Reduction for Terminated Group	Percent Persistence	Percent Persistence 90% Confidence Interval	
		Continued	Terminated				
Spring 1	May 2014	0.2	0.2	0.0	99%	52%	145%
Summer 1	June 2014 - Aug. 2014	0.1	0.1	0.0	178%	26%	330%
Autumn 1	Sept. 2014 - Nov. 2014	0.2	0.2	0.0	81%	21%	142%
Winter 1	Dec. 2014 - Feb. 2015	0.5	0.0	0.5	5%	-35%	46%
Spring 2	Mar. 2015 - May 2015	0.2	0.1	0.1	58%	8%	107%
Summer 2	June 2015 - Aug. 2015	0.1	0.0	0.1	25%	-108%	157%
Autumn 2	Sept. 2015 - Nov. 2015	0.2	-0.1	0.3	-27%	-97%	43%
Winter 2	Dec. 2015 - Feb. 2016	0.4	0.0	0.4	-2%	-74%	69%
Spring 3	Mar. 2016 - May 2016	0.2	0.1	0.1	54%	-15%	123%
Summer 3	June 2016 - Aug. 2016	0.1	0.1	0.0	112%	-3%	228%
Autumn 3	Sept. 2016 - Nov. 2016	0.2	0.1	0.1	38%	-30%	106%
Winter 3	Dec. 2016 - Feb. 2017	0.4	-0.1	0.5	-15%	-104%	73%
Spring 4	Mar. 2017 - May 2017	0.2	0.1	0.1	40%	-36%	116%
Summer 4	June 2017 - Aug. 2017	0.1	0.1	0.0	130%	-14%	274%
Autumn 4	Sept. 2017 - Nov. 2017	0.2	0.1	0.1	54%	-47%	154%
Winter 4	Dec. 2017 - Feb. 2018	0.5	0.0	0.5	1%	-71%	72%
Spring 5	Mar. 2018 - May 2018	0.3	0.0	0.3	10%	-55%	76%
Summer 5	June 2018 - Aug. 2018	0.2	0.2	0.0	119%	31%	207%
Autumn 5	Sept. 2018 - Nov. 2018	0.3	0.1	0.3	25%	-32%	83%
Winter 5	Dec. 2018 - Feb. 2019	0.6	0.1	0.6	9%	-61%	79%
Spring 6	Mar. 2019 - Apr. 2019	0.4	0.2	0.2	45%	-10%	101%

Figure 4-4 and Table 4-5 show the year-to-year and season-to-season gas savings, respectively, of the Gamma Reduced wave. Unlike in the gas savings results for the Gamma Standard wave, but like the results in the electric savings section, there is a downward trend in savings of the terminated group relative to the continued group. Given the wide confidence intervals, however, only the difference in Year 5 is statistically significant at the 90% level. The savings of the terminated customers was 13% of the savings of the continued customers in Year 5, with a confidence interval of -71% to 96%.

Unlike the gas savings for the Gamma Standard wave, the statistical significance of savings for the Gamma Reduced wave does not appear to have any seasonal trend. The first winter season, the fifth summer season, and the final spring season are the only statistically significant estimates. As was the case with the electric savings of the Gamma Reduced wave, although most years have no statistical significance overall, the trend is downward, and if the persistence study is continued into future years, there are likely to be additional results that reach the bar for statistical significance.

Figure 4-4: Annual Gas Savings Persistence - Gamma Reduced Wave

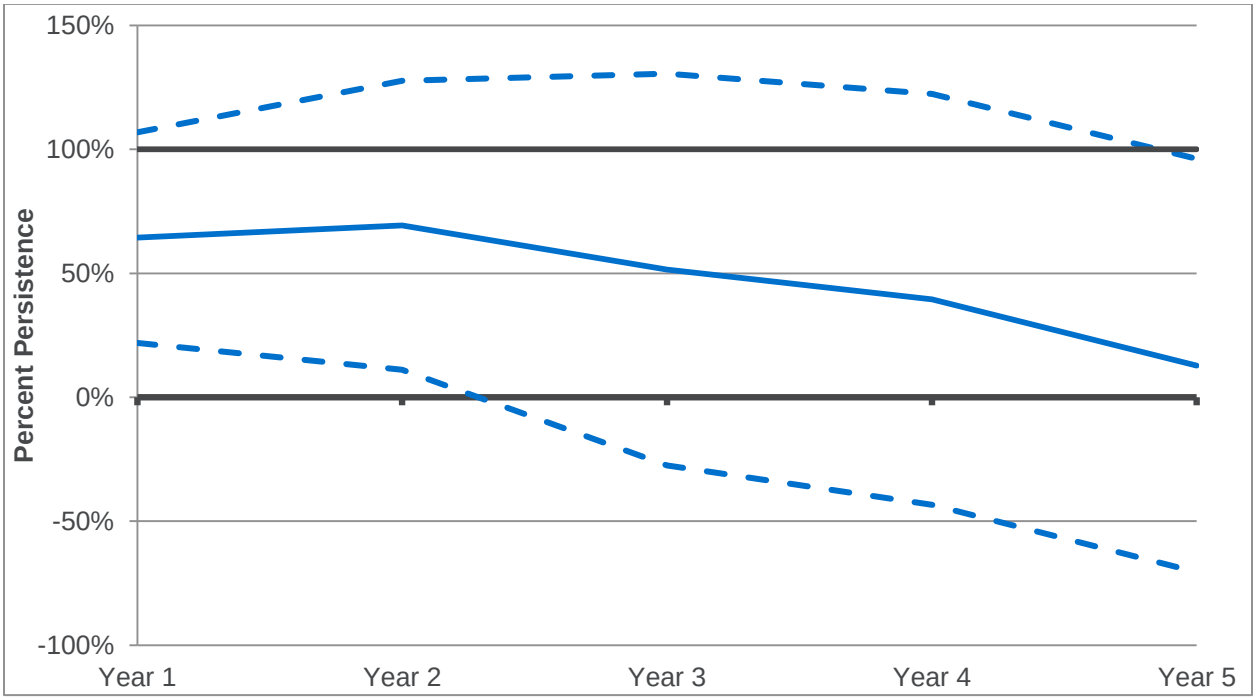

Table 4-5: Seasonal Gas Savings - Gamma Reduced Wave

Season	Time Frame	Monthly Therm Savings		Savings Reduction for Terminated Group	Percent Persistence	Percent Persistence 90% Confidence Interval	
		Continued	Terminated				
Spring 1	May 2014	0.2	0.2	0.0	88%	24%	151%
Summer 1	June 2014 - Aug. 2014	0.0	0.0	0.1	-78%	-281%	125%
Autumn 1	Sept. 2014 - Nov. 2014	0.2	0.2	0.0	111%	41%	180%
Winter 1	Dec. 2014 - Feb. 2015	0.6	0.3	0.2	59%	19%	98%
Spring 2	Mar. 2015 - May 2015	0.2	0.1	0.1	64%	-1%	129%
Summer 2	June 2015 - Aug. 2015	0.0	0.0	0.1	-94%	-437%	249%
Autumn 2	Sept. 2015 - Nov. 2015	0.2	0.1	0.0	81%	-13%	175%
Winter 2	Dec. 2015 - Feb. 2016	0.6	0.4	0.1	75%	20%	129%
Spring 3	Mar. 2016 - May 2016	0.2	0.2	0.0	88%	12%	163%
Summer 3	June 2016 - Aug. 2016	0.1	0.0	0.1	-31%	-244%	182%
Autumn 3	Sept. 2016 - Nov. 2016	0.2	0.1	0.1	56%	-46%	158%
Winter 3	Dec. 2016 - Feb. 2017	0.5	0.2	0.3	39%	-42%	120%
Spring 4	Mar. 2017 - May 2017	0.2	0.2	0.0	108%	20%	196%
Summer 4	June 2017 - Aug. 2017	0.0	0.0	0.0	10%	-376%	396%
Autumn 4	Sept. 2017 - Nov. 2017	0.1	0.0	0.1	19%	-117%	155%
Winter 4	Dec. 2017 - Feb. 2018	0.5	0.1	0.3	32%	-47%	110%
Spring 5	Mar. 2018 - May 2018	0.3	0.1	0.1	48%	-35%	131%
Summer 5	June 2018 - Aug. 2018	0.1	-0.1	0.2	-80%	-227%	67%
Autumn 5	Sept. 2018 - Nov. 2018	0.2	0.1	0.1	64%	-34%	162%
Winter 5	Dec. 2018 - Feb. 2019	0.4	0.0	0.4	4%	-99%	106%
Spring 6	Mar. 2019 - Apr. 2019	0.3	0.0	0.3	13%	-68%	93%

5 Electronic HERs

In April 2014, approximately 220,000 HER recipients in Wave One, Wave Two, and Wave Three began receiving electronic HERs (eHERs) in addition to the standard paper HERs. These households receive eHERs on the months that they do not receive paper reports (i.e., every other month), so that customers receiving eHERs are effectively receiving 12 reports per year. Electronic HERs were withheld from a sample of 81,000 HER recipients in the same experimental waves (the baseline group), thereby allowing for the measurement of the incremental effect of eHERs (as compared to the effect of paper HERs alone). Additionally, a sample of 72,000 non-recipient households served as a control group for both the treatment and baseline groups (for the purpose of measuring energy savings). All three samples consist of PG&E customers who are eligible to receive e-mails from PG&E (i.e., PG&E had e-mail addresses on file and customer permission to send e-mails). These customers have slightly higher electricity consumption than customers for whom PG&E does not have email addresses, which means the results reported in this section are not directly comparable to those reported in Section 2. Table 5-1 presents the number of customers in the baseline, treatment, and control groups by experimental wave.

Table 5-1: eHER Households by Experimental Wave

Experimental Wave	Baseline	Treatment	Control
Wave One	21,367	93,500	28,348
Wave Two	20,850	82,500	16,111
Wave Three	39,041	44,000	27,697

The methodology for estimating the incremental savings of eHERs is identical to that used for measuring energy impacts of the persistence test. The pre-treatment period is defined to be the full year prior to the launch of eHERs. This methodology requires at least one year of HER treatment data prior to the introduction of eHERs. Wave Three was launched in July 2013, which means there is not a full year of HER treatment data prior to the introduction of eHERs that can be used to estimate the incremental savings. As such, the incremental impacts of eHERs were only estimated for Wave One and Wave Two.

Figure 5-1 and Figure 5-2 provide the clearest illustration of the incremental impact of eHERs across the five years of the study, and Table 5-2 and Table 5-3 display the electric energy savings estimates for the baseline and eHER treatment groups for Wave One and Wave Two, respectively, for each successive season of the experiment. The annual incremental impacts for receiving eHERs in addition to paper reports are not statistically significant for either experimental wave for any year, with the exception of Year 4 for Wave Two. To reiterate, the addition of eHERs on the months where customers would not have received any report was generally not found to add any measurable incremental energy savings. The data in the tables is presented at a seasonal level in order to aid in observing long-term trends in the data,

although in both waves there is no clear seasonal trend. The lack of statistical significance overall is primarily due to three factors: the small magnitude of the incremental savings, the high month-to-month variability of savings, and the relatively small eHER population.

PG&E has not tested the impact of sending only eHERs to customers, but this idea has been tested elsewhere. Other studies have found that the savings achieved by eHERs alone are generally smaller than those achieved by paper HERs, but this varies by geographic location.

Figure 5-1: Annual Incremental Electric Savings – Wave One

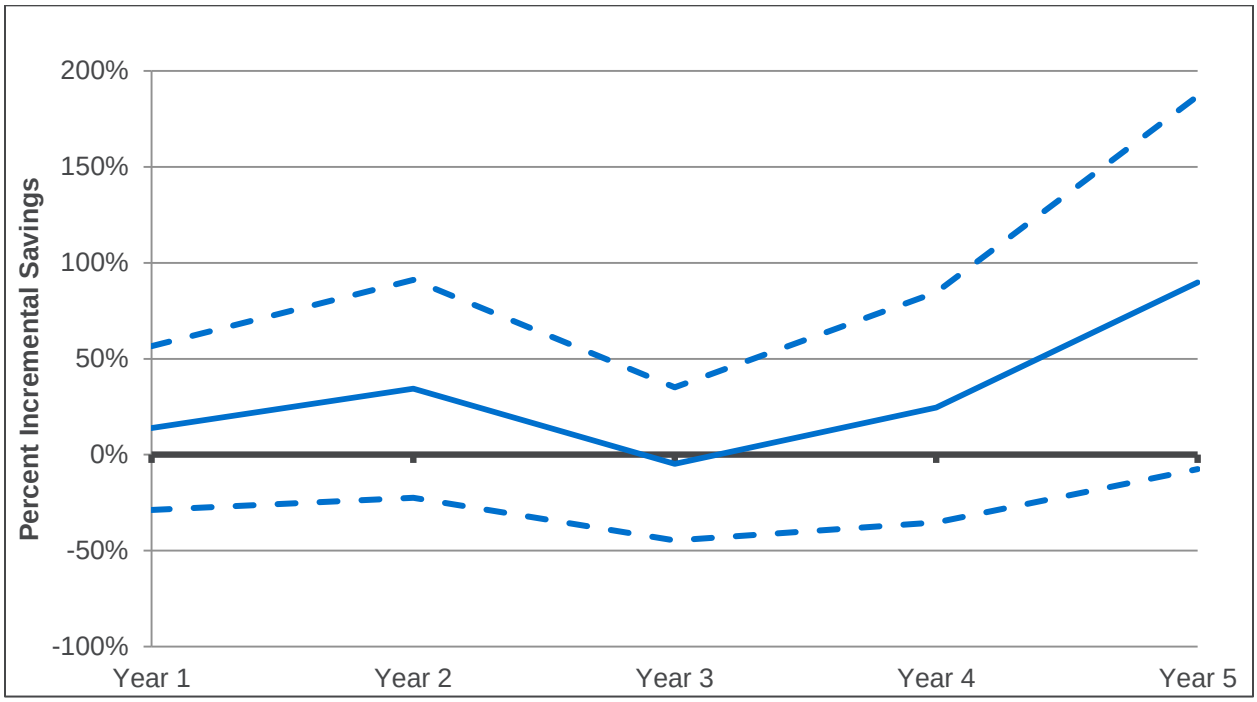

Table 5-2: Seasonal Electric Savings – Wave One

Season	Time Frame	Monthly kWh Savings		Incremental Savings from eHERs	% Incremental Savings	90% Confidence Interval	
		No eHERs	eHERs				
Spring 1	Apr. 2014 - May 2014	3.1	3.6	0.5	14%	-49%	78%
Summer 1	June 2014 - Aug. 2014	2.1	3.1	0.9	43%	-75%	161%
Autumn 1	Sept. 2014 - Nov. 2014	4.3	4.4	0.1	2%	-42%	46%
Winter 1	Dec. 2014 - Feb. 2015	5.6	6.2	0.6	11%	-22%	45%
Spring 2	Mar. 2015 - May 2015	1.3	2.6	1.2	91%	-86%	268%
Summer 2	June 2015 - Aug. 2015	3.5	6.0	2.5	74%	-21%	168%
Autumn 2	Sept. 2015 - Nov. 2015	4.2	5.3	1.1	26%	-34%	86%
Winter 2	Dec. 2015 - Feb. 2016	6.9	7.3	0.4	6%	-29%	41%
Spring 3	Mar. 2016 - May 2016	5.8	5.4	-0.4	-7%	-59%	46%
Summer 3	June 2016 - Aug. 2016	9.3	7.8	-1.5	-16%	-60%	27%
Autumn 3	Sept. 2016 - Nov. 2016	5.9	6.2	0.3	5%	-42%	51%
Winter 3	Dec. 2016 - Feb. 2017	7.4	7.9	0.5	7%	-31%	45%
Spring 4	Mar. 2017 - May 2017	3.6	4.5	0.9	25%	-74%	123%
Summer 4	June 2017 - Aug. 2017	8.4	9.4	1.0	12%	-45%	69%
Autumn 4	Sept. 2017 - Nov. 2017	5.0	6.5	1.5	30%	-34%	93%
Winter 4	Dec. 2017 - Feb. 2018	5.3	6.3	1.0	19%	-39%	78%
Spring 5	Mar. 2018 - May 2018	0.9	5.1	4.2	464%	19%	910%
Summer 5	June 2018 - Aug. 2018	5.7	8.7	3.0	53%	-35%	142%
Autumn 5	Sept. 2018 - Nov. 2018	3.9	7.3	3.4	89%	1%	176%
Winter 5	Dec. 2018	6.0	8.6	2.6	44%	-15%	103%

Figure 5-2 presents the annual incremental electric savings for Wave Two customers receiving eHERs (versus those who receive paper-only HERs). With the exception of the fourth year, the incremental savings are not statistically significant in any year, however the trend is positive.

Figure 5-2: Annual Incremental Electric Savings – Wave Two

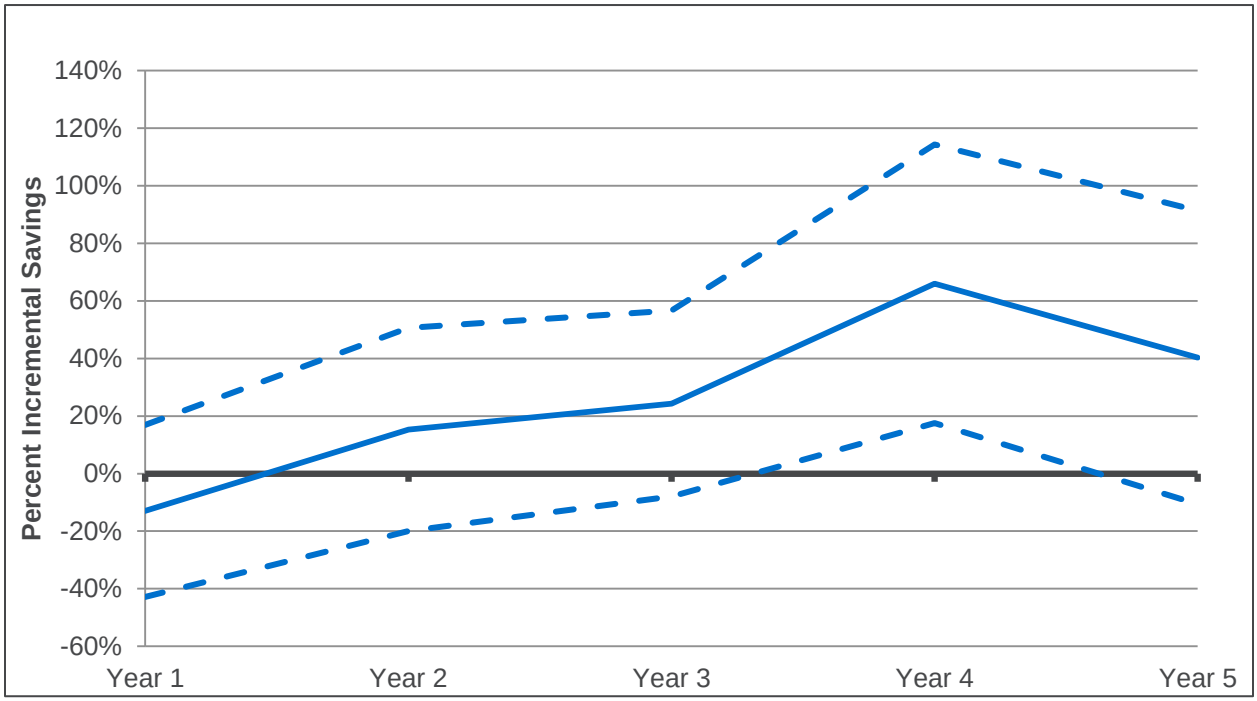

Table 5-3: Seasonal Electric Savings – Wave Two

Season	Time Frame	Monthly kWh Savings		Incremental Savings from eHERs	% Incremental Savings	90% Confidence Interval	
		No eHERs	eHERs				
Spring 1	April 2014 - May 2014	5.1	3.1	-2.0	-39%	-84%	5%
Summer 1	June 2014 - Aug. 2014	6.2	5.7	-0.4	-7%	-48%	34%
Autumn 1	Sept. 2014 - Nov. 2014	4.8	4.4	-0.4	-8%	-51%	36%
Winter 1	Dec. 2014 - Feb. 2015	7.0	6.1	-0.9	-13%	-42%	16%
Spring 2	Mar. 2015 - May 2015	3.5	4.2	0.6	17%	-51%	86%
Summer 2	June 2015 - Aug. 2015	7.1	9.1	2.0	28%	-18%	74%
Autumn 2	Sept. 2015 - Nov. 2015	7.8	8.0	0.2	3%	-30%	36%
Winter 2	Dec. 2015 - Feb. 2016	7.3	8.2	0.9	12%	-23%	47%
Spring 3	Mar. 2016 - May 2016	7.0	8.2	1.2	18%	-25%	60%
Summer 3	June 2016 - Aug. 2016	10.7	13.3	2.7	25%	-12%	63%
Autumn 3	Sept. 2016 - Nov. 2016	8.8	10.3	1.5	16%	-15%	48%
Winter 3	Dec. 2016 - Feb. 2017	8.7	11.1	2.4	28%	-6%	62%
Spring 4	Mar. 2017 - May 2017	6.4	10.3	4.0	62%	7%	118%
Summer 4	June 2017 - Aug. 2017	9.5	15.9	6.4	68%	18%	117%
Autumn 4	Sept. 2017 - Nov. 2017	6.9	10.1	3.2	47%	1%	93%
Winter 4	Dec. 2017 - Feb. 2018	4.2	8.4	4.3	103%	24%	181%
Spring 5	Mar. 2018 - May 2018	5.4	8.7	3.4	62%	-12%	137%
Summer 5	June 2018 - Aug. 2018	8.4	13.5	5.2	62%	2%	122%
Autumn 5	Sept. 2018 - Nov. 2018	7.9	9.6	1.7	22%	-24%	68%
Winter 5	Dec. 2018	9.8	10.0	0.2	2%	-37%	40%

Figure 5-3 and Figure 5-4 present the yearly trends of incremental gas energy savings across the five years of the study for Wave One and Wave Two, respectively, and Table 5-4 and Table 5-5 show the estimated incremental gas savings for Wave One and Wave Two, respectively, for each successive season of the experiment. Unlike in the results for electric savings, sending eHERs to customers in Wave One resulted in statistically significant incremental gas savings for every year of the study. On average over the entire 57-month life of the study, Wave One customers receiving eHERs saved an additional 0.17 therms per month as compared to Wave One customers not receiving eHERs. Conversely, the Wave Two results, presented in Table 5-5, show statistically significant negative incremental savings for years two and five of the study. This result is in part driven by negative incremental savings estimates during winter seasons, which drives the yearly estimate down due to the typically higher gas usages during the winter.

Figure 5-3: Annual Incremental Gas Savings – Wave One

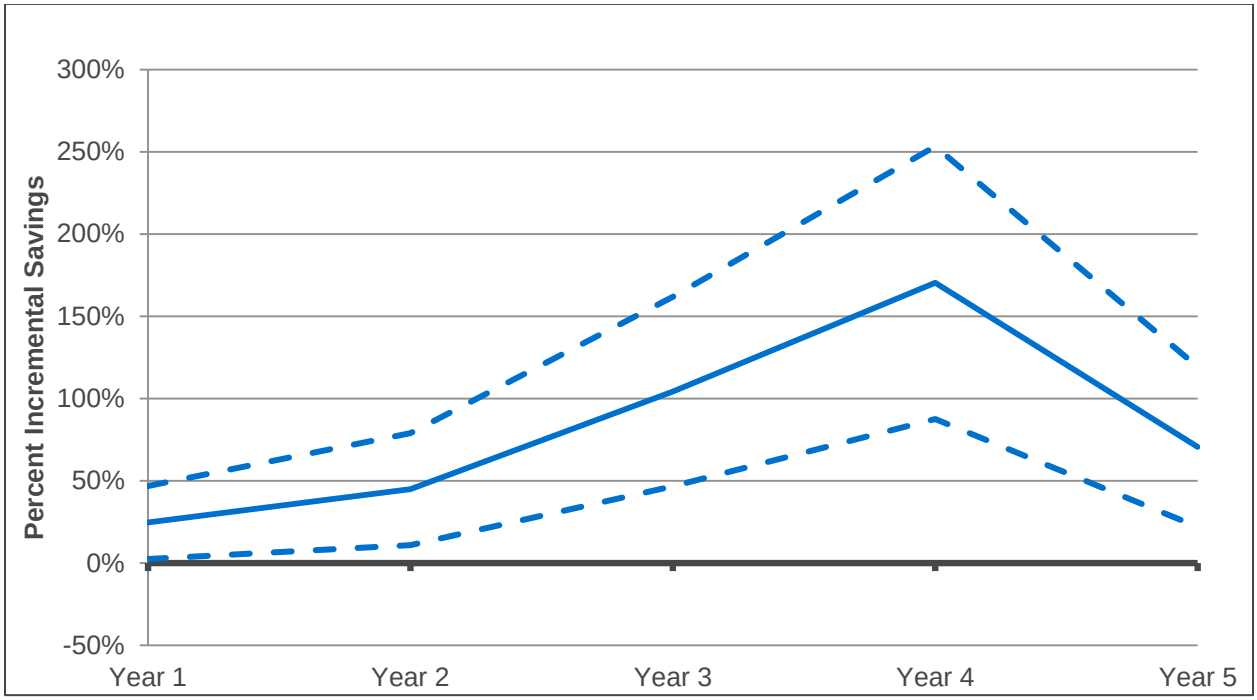

Table 5-4: Seasonal Gas Savings – Wave One

Season	Time Frame	Monthly Therm Savings		Incremental Savings from eHERs	% Incremental Savings	90% Confidence Interval	
		No eHERs	eHERs				
Spring 1	April 2014 - May 2014	0.5	0.4	0.0	-3%	-23%	18%
Summer 1	June 2014 - Aug. 2014	0.2	0.3	0.0	7%	-23%	37%
Autumn 1	Sept. 2014 - Nov. 2014	0.3	0.3	0.1	20%	-12%	52%
Winter 1	Dec. 2014 - Feb. 2015	0.4	0.6	0.3	75%	29%	121%
Spring 2	Mar. 2015 - May 2015	0.3	0.4	0.1	17%	-15%	48%
Summer 2	June 2015 - Aug. 2015	0.2	0.2	0.1	37%	-9%	84%
Autumn 2	Sept. 2015 - Nov. 2015	0.3	0.5	0.1	33%	0%	65%
Winter 2	Dec. 2015 - Feb. 2016	0.4	0.6	0.3	73%	11%	135%
Spring 3	Mar. 2016 - May 2016	0.3	0.5	0.1	39%	3%	75%
Summer 3	June 2016 - Aug. 2016	0.2	0.3	0.1	70%	18%	121%
Autumn 3	Sept. 2016 - Nov. 2016	0.2	0.4	0.2	118%	49%	186%
Winter 3	Dec. 2016 - Feb. 2017	0.2	0.5	0.4	250%	59%	441%
Spring 4	Mar. 2017 - May 2017	0.2	0.4	0.2	86%	17%	156%
Summer 4	June 2017 - Aug. 2017	0.2	0.3	0.1	48%	4%	92%
Autumn 4	Sept. 2017 - Nov. 2017	0.1	0.4	0.2	194%	88%	301%
Winter 4	Dec. 2017 - Feb. 2018	0.1	0.6	0.5	705%	311%	1098%
Spring 5	Mar. 2018 - May 2018	0.2	0.6	0.4	168%	80%	257%
Summer 5	June 2018 - Aug. 2018	0.3	0.3	0.1	32%	-10%	74%
Autumn 5	Sept. 2018 - Nov. 2018	0.3	0.5	0.2	54%	6%	102%
Winter 5	Dec. 2018	0.3	0.6	0.3	83%	-26%	193%

Figure 5-4: Annual Incremental Gas Savings – Wave Two

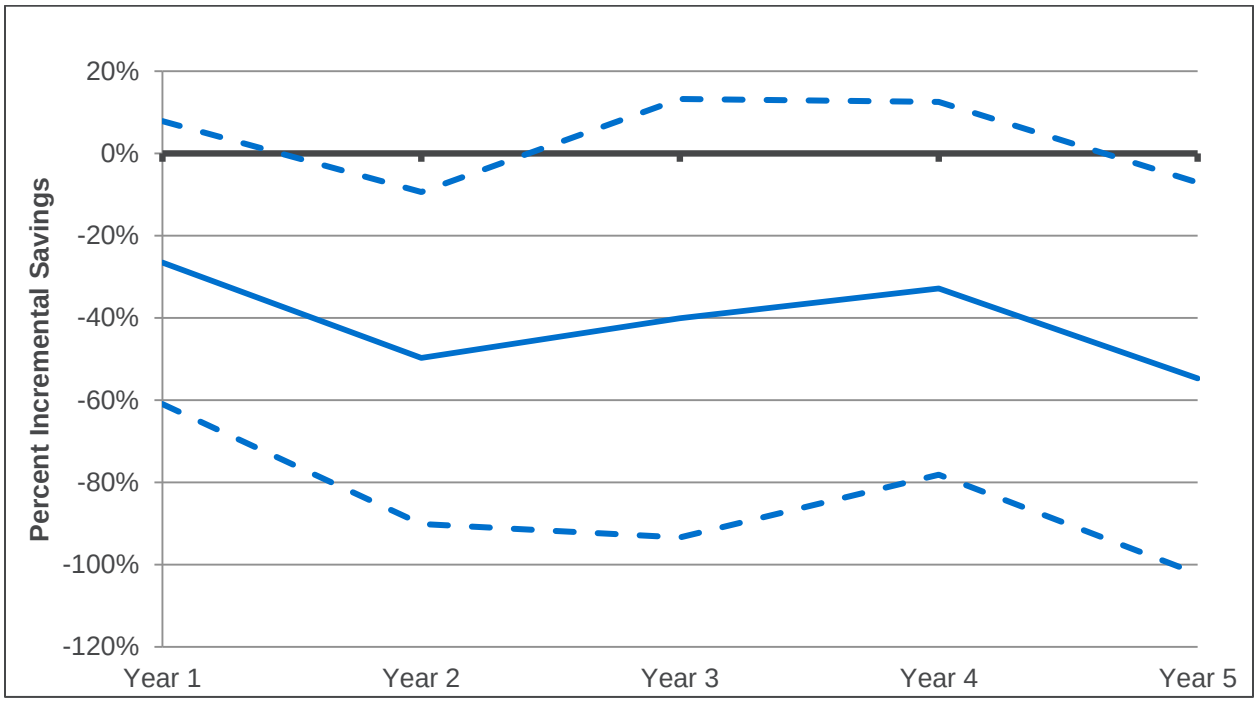

Table 5-5: Seasonal Gas Savings – Wave Two

Season	Time Frame	Monthly Therm Savings		Incremental Savings from eHERs	% Incremental Savings	90% Confidence Interval	
		No eHERs	eHERs				
Spring 1	April 2014 - May 2014	0.3	0.2	-0.1	-30%	-65%	5%
Summer 1	June 2014 - Aug. 2014	0.1	0.1	0.0	-35%	-95%	25%
Autumn 1	Sept. 2014 - Nov. 2014	0.2	0.1	0.0	-18%	-76%	41%
Winter 1	Dec. 2014 - Feb. 2015	0.3	0.2	-0.1	-40%	-91%	11%
Spring 2	Mar. 2015 - May 2015	0.3	0.3	0.0	-7%	-42%	28%
Summer 2	June 2015 - Aug. 2015	0.1	0.1	0.0	0%	-58%	58%
Autumn 2	Sept. 2015 - Nov. 2015	0.3	0.2	-0.1	-30%	-68%	9%
Winter 2	Dec. 2015 - Feb. 2016	0.3	-0.1	-0.4	-125%	-198%	-52%
Spring 3	Mar. 2016 - May 2016	0.1	0.1	0.0	-24%	-112%	65%
Summer 3	June 2016 - Aug. 2016	0.1	0.1	0.0	0%	-75%	76%
Autumn 3	Sept. 2016 - Nov. 2016	0.2	0.2	0.0	-15%	-83%	53%
Winter 3	Dec. 2016 - Feb. 2017	0.5	0.1	-0.3	-71%	-133%	-9%
Spring 4	Mar. 2017 - May 2017	0.3	0.3	0.0	8%	-55%	71%
Summer 4	June 2017 - Aug. 2017	0.1	0.2	0.1	75%	-47%	197%
Autumn 4	Sept. 2017 - Nov. 2017	0.3	0.2	-0.1	-34%	-88%	20%
Winter 4	Dec. 2017 - Feb. 2018	0.6	0.2	-0.4	-71%	-118%	-23%
Spring 5	Mar. 2018 - May 2018	0.3	0.2	-0.1	-25%	-86%	36%
Summer 5	June 2018 - Aug. 2018	0.2	0.1	-0.1	-48%	-126%	30%
Autumn 5	Sept. 2018 - Nov. 2018	0.3	0.1	-0.2	-61%	-110%	-12%
Winter 5	Dec. 2018	0.6	0.1	-0.5	-80%	-139%	-21%

Appendix A Inputs to Upstream Joint Savings Estimates

Table A-1: CFL Inputs

Year	CFL									
	kWh Savings per Lamp	Therm Effects per Lamp	Avg. Percent of Bulbs installed per month in 2018	Rebated Sales Fraction	Installation Rate	NTG	Fraction of Lamps in 2014	Percent Installed During Peak	Delta Watts	Peak Coincidence Factor
2011	26.8	-0.8	1.00	0.50	0.97	0.63	1.00	1.00	25.2	0.05
2012	26.2	-0.8	1.00	0.45	0.97	0.63	1.00	1.00	25.2	0.05
2013	23.5	-0.8	1.00	0.16	0.97	0.31	1.00	1.00	25.2	0.05
2014	23.5	-0.8	1.00	0.07	0.97	0.31	0.66	1.00	25.2	0.05
2015	23.5	-0.3	1.00	0.09	1.00	0.31	1.00	1.00	25.2	0.05
2016	16.0	-0.3	1.00	0.09	1.00	0.47	1.00	1.00	25.2	0.05
2017	16.0	-0.3	1.00	0.09	1.00	0.47	1.00	1.00	25.2	0.05
2018	33.0	-0.7	0.54	0.09	1.00	0.22	1.00	0.52	25.2	0.05

Table A-2: LED Inputs

Year	LED									
	kWh Savings per Lamp	Therm Effects per Lamp	Avg. Percent of Bulbs installed per month in 2018	Rebated Sales Fraction	Installation Rate	NTG	Fraction of Lamps in 2014	Percent Installed During Peak	Delta Watts	Peak Coincidence Factor
2011	0.0	-0.71	1.00	0.00	0.99	0.00	1.00	1.00	36.70	0.06
2012	0.0	-0.71	1.00	0.00	0.99	0.00	1.00	1.00	36.70	0.06
2013	24.8	-0.71	1.00	0.00	0.99	0.45	1.00	1.00	36.70	0.06
2014	24.8	-0.71	1.00	0.21	0.99	0.45	0.34	1.00	36.70	0.06
2015	24.8	-0.63	1.00	0.20	1.00	0.45	1.00	1.00	36.70	0.06
2016	28.5	-0.63	1.00	0.20	1.00	0.33	1.00	1.00	36.70	0.06
2017	28.5	-0.63	1.00	0.20	1.00	0.33	1.00	1.00	36.70	0.06
2018	15.4	-0.61	0.54	0.20	1.00	0.33	1.00	0.52	36.70	0.06

Table A-3: Annual Additional CFLs per Customer

Wave	Wave Launch	Avg. Number of Treatment Customers in 2018	Year 1 (Month 1 through 12 or Month 1 through Dec. 2014)[1]	Year 2 (Month 13 through Month 24 or Month 13 through Dec. 2014)	Year 3 (Month 25 through Month 36 or Month 25 through Dec. 2014)	Year 4 (Month 37 through Month 48 or Month 37 through Dec. 2014)	2015	2016	2017	2018
Beta	Jul-11	36,512	0.95	0.40	0.15	0.08	-0.17	0.02	0.02	0.02
Gamma Standard	Nov-11	41,935	0.95	0.40	0.15	0.08	0.17	1.09	1.09	1.09
Gamma Reduced	Nov-11	41,969	0.95	0.40	0.15	0.08	0.01	0.41	0.41	0.41
Gamma Electric Only	Nov-11	19,883	0.95	0.40	0.15	0.08	-0.07	-0.69	-0.69	-0.69
Wave 1	Mar-12	219,642	0.95	0.40	0.15	0.08	0.02	0.13	0.13	0.13
Wave 1 - Electric Only	Mar-12	19,898	0.95	0.40	0.15	0.08	0.61	0.13	0.13	0.13
Wave 2 - Area 7	Feb-13	19,898	0.95	0.40	0.15	0.08	0.02	0.40	0.40	0.40
Wave 2 - Non-Area 7	Feb-13	198,819	0.95	0.40	0.15	0.08	0.01	-1.14	-1.14	-1.14
Wave 3	Jul-13	132,881	0.95	0.40	0.15	0.08	0.09	0.10	0.10	0.10
Wave 4	Mar-14	110,372	0.95	0.40	0.15	0.08	-0.16	-0.95	-0.95	-0.95
Wave 5	Oct-14	130,449	0.95	0.40	0.15	0.08	0.00	0.72	0.72	0.72
Wave 6	Sep-15	191,137	NA	NA	NA	NA	0.03	0.74	0.74	0.74
Wave 7	Mar-17	123,720	NA	NA	NA	NA	NA	NA	-0.41	-0.41
Wave 8	Nov-17	127,996	NA	NA	NA	NA	NA	NA	-0.41	-0.41
Wave 9	Sep-18	96,929	NA	NA	NA	NA	NA	NA	NA	-0.41

[1] Values in this table are at the annual level, however the uplift is calculated separately for each month. For 2011 through 2014, the annual uplift was estimated on a treatment-year basis. Starting in 2015, the annual uplift was estimated on a calendar-year basis instead. For the first year of treatment before 2015, an annual uplift of 0.95 bulbs per customer is applied for each month for the first twelve months or until December 2014, whichever happened first. A similar assumption is made through Year 4.

Table A-4: Annual Additional LEDs per Customer

Wave	Wave Launch	Avg. Number of Treatment Customers in 2018	Year 1 (Month 1 through 12 or Month 1 through Dec. 2014)	Year 2 (Month 13 through Month 24 or Month 13 through Dec. 2014)	Year 3 (Month 25 through Month 36 or Month 25 through Dec. 2014)	Year 4 (Month 37 through Month 48 or Month 37 through Dec. 2014)	2015	2016	2017	2018
Beta	Jul-11	36,512	0.95	0.40	0.15	0.08	0.09	0.36	0.36	0.36
Gamma Standard	Nov-11	41,935	0.95	0.40	0.15	0.08	0.33	-0.53	-0.53	-0.53
Gamma Reduced	Nov-11	41,969	0.95	0.40	0.15	0.08	0.44	-0.27	-0.27	-0.27
Gamma Electric Only	Nov-11	19,883	0.95	0.40	0.15	0.08	0.23	1.95	1.95	1.95
Wave 1	Mar-12	219,642	0.95	0.40	0.15	0.08	0.71	1.32	1.32	1.32
Wave 1 - Electric Only	Mar-12	19,898	0.95	0.40	0.15	0.08	0.24	1.32	1.32	1.32
Wave 2 - Area 7	Feb-13	19,898	0.95	0.40	0.15	0.08	0.51	-0.95	-0.95	-0.95
Wave 2 - Non-Area 7	Feb-13	198,819	0.95	0.40	0.15	0.08	0.55	0.86	0.86	0.86
Wave 3	Jul-13	132,881	0.95	0.40	0.15	0.08	0.09	0.16	0.16	0.16
Wave 4	Mar-14	110,372	0.95	0.40	0.15	0.08	-0.09	-0.28	-0.28	-0.28
Wave 5	Oct-14	130,449	0.95	0.40	0.15	0.08	0.11	-0.28	-0.28	-0.28
Wave 6	Sep-15	191,137	NA	NA	NA	NA	0.29	-0.03	-0.03	-0.03
Wave 7	Mar-17	123,720	NA	NA	NA	NA	NA	NA	-1.08	-1.08
Wave 8	Nov-17	127,996	NA	NA	NA	NA	NA	NA	-1.08	-1.08
Wave 9	Sep-18	96,929	NA	NA	NA	NA	NA	NA	NA	-1.08

Table A-5: Sources for Upstream Joint Savings Estimate

Input	Source
Annual Additional Bulbs	Year 1: 2012 PG&E in-home survey (FSC, now Nexant) Year 2: Combination of PG&E and PSE uplift estimates Year 3: 2013 PSE HER phone survey (DNV GL) Year 4: 2014 PSE HER phone survey (DNV GL) 2015: 2015 Online Survey (DNV GL) 2016 - 2018: 2016-2017 Online Survey (DNV GL)
kWh Savings per Lamp	2011 - 2012: 2010-12 ULP Evaluation (DNV GL)
	2013 - 2015: Program Tracking Data (DEER)
	2016 - 2017: 2015 ULP Evaluation (DNV GL)
	2018: 2017 ULP Evaluation (DNV GL)
Therm Effects per Lamp	2011 - 2014: 2013-14 ULP Evaluation (DNV GL)
	2015 - 2017: 2015 ULP Evaluation (DNV GL)
	2018: 2017 ULP Evaluation (DNV GL)
Rebated Sales Fraction	2011 - 2014: 2014 HER Lighting Overlap Study (TRC)
	2015 - 2018: 2015 HER Lighting Overlap Study (TRC)
Installation Rate	2011 - 2014: 2013-14 ULP Evaluation (DNV GL)
	2015 - 2018: Uplift is defined to be the uplift in *installed* bulbs
NTG	2011 - 2012: 2010-12 ULP Evaluation (DNV GL)
	2013 - 2014: 2013-14 ULP Evaluation (DNV GL)
	2016 - 2017: 2015 ULP Evaluation (DNV GL)
	2018: 2017 ULP Evaluation (DNV GL)
Fraction of Lamps in 2014	2014: 2014 HER lighting overlap study (TRC)
Proportion of Lamps in Place During Peak	2018: Peak period began on 190 day of the year; 190/365
Delta Watts	2011 - 2017: 2015 ULP Evaluation (DNV GL)
	2018: 2017 ULP Evaluation (DNV GL)
Peak Coincidence Factor	2011 - 2017: 2015 ULP Evaluation (DNV GL)
	2018: 2017 ULP Evaluation (DNV GL)

Appendix B Demand Savings CAISO & PG&E Peaks

In addition to estimating demand savings for the 2018 heat wave, peak reductions were also estimated for the CAISO and PG&E peak demand hours. The 2018 CAISO system peak occurred on July 25th from 5 PM to 6 PM. The impact of HERs during this hour was 32.6 MW, shown in Table A-6. The impact (kW) values were calculated by subtracting the demand from 5 PM to 6 PM for the treatment customers from the demand from 5 PM to 6 PM for the control customers.

Table A-6: CAISO System Peak Demand Reductions by Experimental Wave

Wave	Number of Control Residences	Number of Treated Residences	Control Load (kW)	Treatment Load (kW)	Impact (kW)	Percent Impact	95% Confidence Interval		Aggregate Impact (MW)	Temperature (F)
Beta	37,691	37,471	2.68	2.61	0.06	2.4%	0.03	0.10	2.4	86
Gamma	43,037	43,048	2.17	2.16	0.01	0.5%	-0.02	0.04	0.4	93
Gamma Electric	20,333	20,302	1.94	1.91	0.03	1.5%	-0.01	0.07	0.6	94
Gamma Reduced	43,037	42,889	2.17	2.16	0.01	0.4%	-0.02	0.04	0.4	93
Wave 1	56,034	223,671	1.94	1.92	0.02	1.2%	0.01	0.04	5.3	88
Wave 1 Electric	5,092	20,148	2.52	2.54	-0.02	-0.8%	-0.08	0.04	-0.4	97
Wave 2 Area 7	32,520	52,169	0.99	0.97	0.02	2.1%	0.00	0.04	1.1	83
Wave 2 Not Area 7	31,965	204,571	1.68	1.65	0.04	2.4%	0.02	0.06	8.1	84
Wave 3	45,066	135,413	1.64	1.62	0.02	1.3%	0.00	0.04	2.8	84
Wave 4	42,335	112,640	1.55	1.54	0.01	0.8%	-0.01	0.03	1.3	85
Wave 5	31,863	133,724	2.79	2.77	0.01	0.5%	-0.01	0.04	1.7	94
Wave 6	31,056	193,843	1.62	1.60	0.03	1.6%	0.01	0.05	5.1	86
Wave 7	29,165	114,637	1.78	1.77	0.01	0.7%	-0.01	0.04	1.4	87
Wave 8	19,778	128,561	0.51	0.50	0.00	0.9%	-0.01	0.02	0.6	78
Wave 9	19,399	101,727	2.52	2.50	0.02	0.7%	-0.01	0.05	1.8	92
Average/Total	488,371	1,564,814	1.80	1.78	0.02	1.2%	0.01	0.03	32.6	87

The 2018 PG&E system peak occurred on July 25th during the hour of 6 PM to 7 PM. The temperatures were slightly cooler than those during the CAISO peak, and HER recipients provided a load reduction of 31.4 MW during this peak.

Table A-7: PG&E System Peak Demand Reductions by Experimental Wave

Wave	Number of Control Residences	Number of Treated Residences	Control Load (kW)	Treatment Load (kW)	Impact (kW)	Percent Impact	95% Confidence Interval		Aggregate Impact (MW)	Temperature (F)
Beta	37,691	37,471	2.75	2.71	0.04	1.3%	0.01	0.07	1.4	83
Gamma	43,037	43,048	2.22	2.22	0.01	0.3%	-0.02	0.03	0.3	91
Gamma Electric	20,333	20,302	1.98	1.94	0.04	1.9%	0.00	0.07	0.7	92
Gamma Reduced	43,037	42,889	2.22	2.21	0.01	0.5%	-0.01	0.04	0.5	91
Wave 1	56,034	223,671	2.00	1.97	0.03	1.3%	0.01	0.04	5.7	85
Wave 1 Electric	5,092	20,148	2.60	2.61	-0.01	-0.5%	-0.07	0.05	-0.3	95
Wave 2 Area 7	32,520	52,169	1.04	1.02	0.02	1.7%	0.00	0.03	0.9	79
Wave 2 Not Area 7	31,965	204,571	1.74	1.71	0.04	2.1%	0.02	0.06	7.5	81
Wave 3	45,066	135,413	1.70	1.68	0.02	1.4%	0.01	0.04	3.2	82
Wave 4	42,335	112,640	1.61	1.59	0.01	0.8%	-0.01	0.03	1.5	82
Wave 5	31,863	133,724	2.85	2.85	0.00	0.1%	-0.02	0.03	0.3	91
Wave 6	31,056	193,843	1.67	1.64	0.03	1.6%	0.01	0.05	5.2	83
Wave 7	29,165	114,637	1.81	1.80	0.01	0.7%	-0.01	0.04	1.4	84
Wave 8	19,778	128,561	0.53	0.53	0.01	1.1%	-0.01	0.02	0.8	75
Wave 9	19,399	101,727	2.52	2.50	0.02	0.8%	-0.01	0.05	2.2	89
Average/Total	488,371	1,564,814	1.85	1.83	0.02	1.1%	0.01	0.03	31.4	84

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