Impact Evaluation of Smart Thermostats

Residential Sector - Program Year 2018

EM&V Group A

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1 EXECUTIVE SUMMARY

1.1 Background

Smart communicating thermostats are energy management tools that enable customers to regulate their heating, cooling and ventilation energy consumption. Since these are programmable devices, customers can schedule the set points of their homes' cooling and heating systems, so they run during periods when customers need them. These devices can also sense occupancy and 'learn' to adjust temperature settings of the home optimally in a way that may further reduce energy consumption. Since they are WiFi enabled, they allow customers to adjust settings from their smart devices for additional energy use control.

Smart communicating thermostats (SCTs) were offered in a broad variety of energy efficiency programs by Pacific Gas & Electric (PG&E), Southern California Edison (SCE), SoCalGas (SCG), and San Diego Gas & Electric (SDG&E), collectively the Program Administrators or PAs, in 2018. Within these programs, smart thermostats were available either through $50 to $75 rebates or as part of direct install channels that offered smart thermostats at low or no cost to customers.

The programs, which were offered to both electric and gas customers, targeted different population segments including general residential customers and customers in multifamily and mobile home dwellings. In total, approximately 220,000 customers received smart thermostats in program year 2018 via the different programs and delivery channels. The majority of program installations were Nest thermostats, ranging from about 90% at SCG to 77% at SDG&E. Ecobee thermostats were the next most commonly installed program sponsored thermostat. Participation trends indicate that most households bought or received a thermostat in the summer and winter high energy using seasons.

1.2 Research questions and objectives

DNV GL's research objectives were to: estimate the electric and gas savings achieved due to smart thermostat installations in program year 2018; determine to what extent evaluated savings estimates matched claimed savings; and, the percentage of customers who would have acquired the device(s) in the absence of the program. DNV GL also sought to understand the program participant characteristics, including dwelling type, location, general demographic background, energy efficiency program participation, and energy consumption behaviors.

1.3 Study approach

DNV GL's approach to estimate changes in energy consumption, considered a best practice for evaluation of opt-in programs[1], is enshrined in both the CA evaluation protocols and the Uniform Methods Project[2]. In this evaluation, DNV GL:

- Estimated the energy savings of smart thermostats
- Conducted surveys to determine the portion of these savings attributable to program incentives

Savings were estimated based on customers that received smart thermostats via PA energy efficiency incentive programs and did not participate in any other energy efficiency programs.

Strengths. DNV GL selected this approach to isolate the effect of smart thermostats on energy use without the additional complicated accounting where multiple technologies are installed. This approach allows the development of more accurate technology-specific savings estimates.

Limitations. While the technology-specific savings estimates derived are likely to be relatively higher than in cases where customers install multiple technologies, our evaluation applies these savings estimates to all cases.

1.4 Key findings

Total savings. The electric realization rates (ratio of evaluated savings to savings claimed by the PAs) indicate that smart thermostats delivered 14% to 42% of total savings that the PAs expected (Table 1-1). Total savings are further adjusted to reflect the portion of savings that can be attributed to smart thermostat installations due to program incentives using net-to-gross (NTG) ratios. Evaluation results show program attributable savings of 11.1 GWh.

Table 1-1. Total smart thermostat electric savings, 2018

Program Administrator	Program participants (Electric)	Total Gross Claimed Savings (kWh)	Total Gross Evaluated Savings (kWh)	Gross Realization Rate	NTG Ratio	Total Net Evaluated Savings (kWh)
PG&E	35,522	7,582,785	3,191,260	42%	70%	2,242,484
SCE	76,922	17,440,307	6,127,389	35%	84%	5,158,682
SCG	65,557	13,281,679	3,976,667	30%	85%	3,398,535
SDG&E	12,014	3,073,459	428,476	14%	77%	329,355
Statewide	**190,015**	**41,378,231**	**13,723,792**	**33%**	**81%**	**11,129,056**

Note: SCE electric savings per household are used to estimate electric savings for SCG as there is a lot of overlap both in customers served and in the way some of the programs delivered smart thermostats

The gas realization rates ranged from 7% to 37% (Table 1-2). Evaluation results show program attributable gas savings of 348,223 therms.

[1] Opt-in programs are those that customers actively choose to participate in. This is in contrast to programs like Home Energy Reports that automatically enroll customers.

[2] The Uniform Methods Project is a DOE led initiative that defines the protocols to evaluate energy efficiency measures and programs.

Table 1-2. Total smart thermostat gas savings, 2018

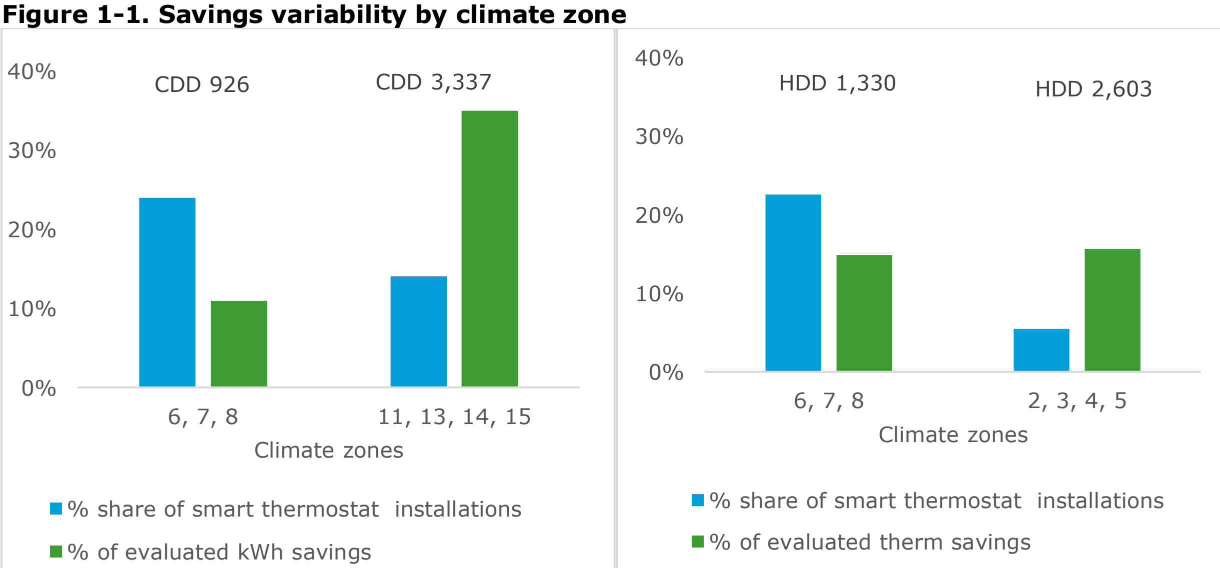
Program Administrator	Program participants (Gas)	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate	NTG Ratio	Total Net Evaluated Savings (therms)
PG&E	35,543	743,211	273,934	37%	70%	192,492
SCE	76,922	833,531	65,865	8%	84%	55,452
SCG	100,496	1,267,756	92,683	7%	85%	79,209
SDG&E	9,496	160,282	27,412	17%	77%	21,071
Statewide	**222,457**	**3,004,781**	**459,894**	**15%**	**76%**	**348,223**

Note: SCG gas savings per household are used to estimate gas savings for SCE as there is overlap both in customers served and in the delivery of the program smart thermostats.

Gross savings[3]. The evaluation found some evidence of cooling and heating savings, particularly in climate zones with high cooling and heating energy consumption. Figure 1-1 presents an example. Smart thermostat installations in climate zones 11, 13, 14 and 15 represent 14% of all installations (3,337 cooling degree days) and deliver 35% of evaluated electric savings (4.8 MWh). Although these climate zones exhibited relatively better performance, this 4.8 MWh still falls short and represents 35% of PA claimed savings for these climate zones (13.6 MWh).

Conversely, climate zones 6,7 and 8 (926 cooling degree days) representing 24% of program installations deliver relatively lower kWh savings of 11% (1.5 MWh). This 1.5 MWh represents 28% of PA claimed savings for these climate zones (5.4 MWh). We see similar patterns with installations in climate zones with high heating load delivering a higher proportion of evaluated savings than installations in milder climates. These results suggest that the program can achieve better results with improved targeting to customers in areas with high cooling and heating loads.

Figure 1-1. Savings variability by climate zone



3 Gross savings are a measure of change in energy use due to energy efficiency programs, regardless of why customers participated.

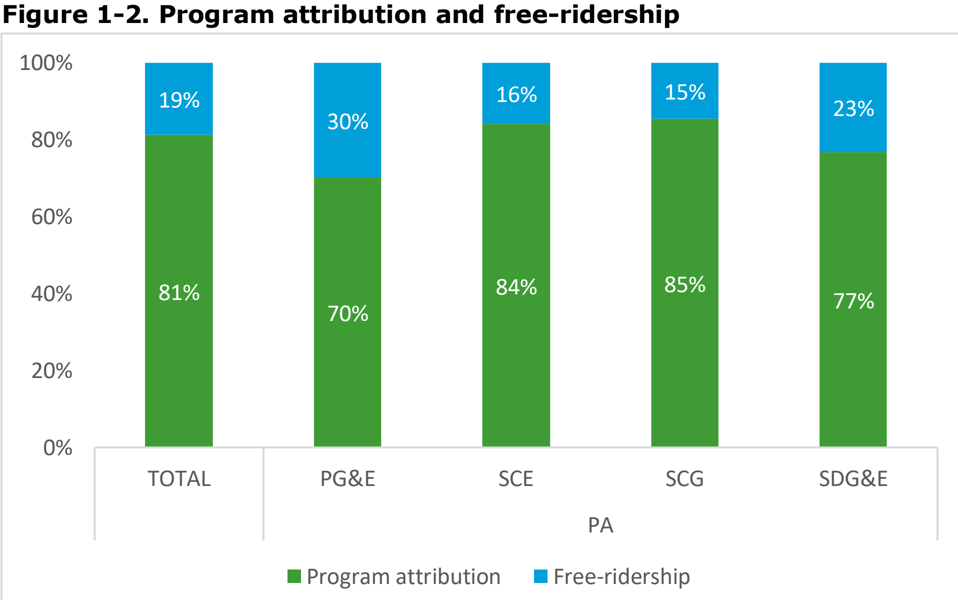
Table 1-3 summarizes the final adjusted savings per household based on these savings. These savings reflect adjustments for the following: 1) increases in energy use unrelated to heating and cooling among customers installing smart thermostats 2) prevalence of smart thermostats among the comparison group, and 3) the proportion of customers with heating and cooling load. We discuss these adjustments in detail in the main report.

Table 1-3. Adjusted cooling and heating load savings per household, 2018

Program Administrator	Electric Load Savings (kWh)	Gas Load Savings (therms)
PG&E	89.8	7.7
SCE	79.7	0.9
SCG	60.7	0.9
SDG&E	35.7	2.9
Statewide	**72.2**	**2.1**

Free-ridership. Free-ridership is defined as the extent of program participation that would have occurred even in the absence of program incentives. Free-ridership ranges from 0% to 100%, with a with a lower value translating to greater program influence on a customer's decision to install the device. The net-to-gross ratio is the complement of free-ridership and measures the amount of savings attributed to program incentives. For example, an 80% NTG ratio indicates 20% free-ridership. DNV GL estimated free-ridership of 19% based on residential program participant and property manager surveys (Figure 1-2). Consequently, while program attribution varies by PA, approximately 81% of overall program savings are directly attributable to the program.

Figure 1-2. Program attribution and free-ridership



Customer characteristics. In addition to informing the proportion of savings for which the program should receive credit, surveys also provide relevant information on customer characteristics related to energy consumption. DNV GL conducted surveys among both participants and non-participants i.e. customers who did not receive program discounted or free smart thermostats. Survey findings indicate that higher proportions of participants tend to be homeowners, reside in newer and larger homes, have central air conditioning, and have higher incomes.

Smart thermostat user profile. Over one-quarter (29%) of all non-participants indicated that they had a smart thermostat. Of these, roughly half installed their thermostat at a time that could potentially contribute to lower estimated savings from the billing analysis.

A comparison of program participants and non-participants on their smart thermostat use reveals that:

- Program participants report enrollment in demand response programs and using the auto-away feature that sets back the thermostat when it does not sense occupancy in the home in higher proportions relative to non-participants with smart thermostats.
- Participants also exhibit thermostat use behaviors that are geared to comfort, remote operation, and pre-heating and pre-cooling the home in higher proportions than non-participants.

While the former actions contribute to savings achieved by participants, the latter actions contribute to increased energy consumption and reduce savings potential.

Load savings shape. This report provides weather-normalized load savings shapes for electric cooling and heating. The load savings shapes are a preliminary, exploratory attempt to establish when during the day smart thermostat savings occur. The cooling load savings shapes, for instance, diverge substantially from the cooling load peak hours. Savings in the afternoon are relatively higher compared to early evenings, indicating that savings may be related to setpoint increases while occupants are at home in the evenings. These kinds of insights can inform calculation of the hourly avoided cost of energy as well as carbon impacts of savings.

The load savings shapes are presented as average hourly shapes for typical weather, but the approach offers the flexibility to look at the load savings shapes for specific days, weather conditions, and geographic areas. The shapes are also derived in a way that is methodologically consistent with annual savings estimate provided in this report. Though there remain details to work out with respect to the underlying experimental design, these results are suggestive of the potential of load savings shapes for this kind of measure.

1.5 Recommendations

Table 1-4 summarizes the findings and recommendations from this evaluation. These findings are discussed in greater detail in the full report.

Table 1-4. Key findings and Recommendations

Key findings	Recommendations & Implications
1. Lower than expected gross savings	Focus savings estimates on actual customer consumption of cooling and heating. Increase targeting and focus in Central Valley for customers with high cooling load. Recognize that smart thermostats have demonstrated demand response and direct load control capabilities that are not assessed in this report.

Key findings	Recommendations & Implications
2. A majority of rebate (80%) and direct-install (60%) participants perform remote mobile app adjustments.	Provide customers with additional information that saving features can be lost if optimizing options are disabled and/or overridden by remote changes.
3. The participant population may have different consumption trends than available comparison group households. This is also supported by evidence from the survey. The potential for self-selection affecting savings estimates is unavoidable when randomized experimental designs are not practical.	Differences between participants and comparison group households point to potential increasing trends in baseload consumption among participants. The next smart thermostat evaluation should develop methods for identifying trends in pre-installation consumption to include as a matching variable as well as other methods to minimize potential self-selection bias. Also, the current study could be updated with a new matched comparison group comprised of more recent program participants who were not available for inclusion within the existing evaluation timeframe.
4. Load savings shapes provide additional insight into what time of day smart thermostat savings occur. The shape of smart thermostat savings appears to diverge from the shape of overall cooling consumption.	Load savings shapes are an increasingly important outcome from studies like this and further research is required to move them beyond the exploratory phase. This should not only provide better estimates of load savings shapes, but also provide annual savings estimates that are consistent with those obtained from other methods, including the two-stage method used in this study.
5. Customer information files do not provide a complete picture of customer dwelling types. While such information is included in Customer Information Systems dataset, there are many instances where the designation does not match what is reported in program tracking data. DNV GL has attempted to identify and match on housing types with mixed success due to the quality of the data.	DNV GL recommends that PAs provide reliable housing type information for the residential population so that future evaluations may include savings estimates that provide insights on where the measure delivers maximum savings.

2 INTRODUCTION

2.1 Program description and participation

Smart communicating thermostats are energy management tools that enable customers to regulate their heating, cooling, and ventilation energy consumption. Similar to programmable thermostats, customers can schedule the set points of their homes' cooling and heating systems, so these systems run during periods when customers need them.[4] In addition, smart communicating thermostats can also sense occupancy and 'learn' to adjust temperature settings of the home optimally in a way that may reduce energy consumption. Since they are Wi-Fi enabled, they allow customers to adjust settings from their smart devices for additional energy use control.

Smart thermostats were offered through 18 different programs across California's PAs in PY 2018 (Table 2-1). These programs provided a mix of energy efficiency measures, including smart thermostats. In general, the programs offered subsidized or free smart thermostats to customers. The programs also targeted different population segments and used different delivery channels (rebates, incentives, or direct installation) for the measures they offered.

Table 2-1. Programs offering smart thermostats, PY 2018

PA	Program Name	Target	Delivery Method	Measures Offered
PG&E	Residential Energy Fitness Program	Income or energy constrained residential customers	Direct Install	Comprehensive or mix of measures, including smart thermostats
SCE	Residential Direct Install Program			
SDG&E	Local-Cals-Middle Income Direct Install (MIDI)			
SCG	RES-Community Language Efficiency Outreach (CLEO)			
PG&E	Plug-Load & Appliances (Residential Energy Efficiency)	All residential customers	Rebates and incentives	Plug load & appliances, including smart thermostats
SCE	Plug Load And Appliances Program			
SCG	RES-Plug-Load & Appliances (Residential Energy Efficiency)			
SDG&E	SW-CALS-Plug Load And Appliances-HEER			
SDG&E	SW-CALS-Plug Load And Appliances-Pos Rebates			
PG&E	Enhance Time Delay Relay	Multifamily customers	Direct Install	Comprehensive or mix of measures, including smart thermostats
SCG	RES-Multifamily Direct Therm Savings ("Energy Smart" Program)			
SDG&E	SW-CALS-Multi-Family Energy Efficiency Rebates (MFEER)			
SCE	Multifamily Energy Efficiency Rebate Program			
SCG	RES-Multi-Family Energy Efficiency Rebates (MFEER)			
SCG	RES-Manufactured Mobile Home	Manufactured and mobile homes	Direct Install	Comprehensive or mix of measures, including smart thermostats
SDG&E	3P-Res-Comprehensive Manufactured-Mobile Home			
SCE	Comprehensive Manufactured Homes			
PG&E	Direct Install for Manufactured and Mobile Homes			

Source: PA Tracking Data filed with the CPUC

[4] We note that not all programmable thermostats are set to run on a schedule. Smart thermostats create schedules even if customers do not set these up and potentially offer opportunities for energy savings.

Statewide, PA programs delivered over 220,000 smart thermostats to customers in 2018. The PAs reported smart thermostats savings claims of approximately 41 million kWh and 3 million therms for 2018 but did not report any demand (MW) savings. Average reported savings were 218 kWh and 14 therms per smart thermostat across all PAs. Table 2-2 provides the total count of smart thermostats with electric and gas savings claims by PA.

Table 2-2. Smart thermostat installations and savings by PA, PY 2018

Program Administrator	Installations with Electric Savings Claims	Installations with Gas Savings Claims	Gross First Year Electric Savings (kWh)	Gross First Year Gas Savings (therms)	Gross Unit Electric Savings (kWh)	Gross Unit Gas Savings (therms)
PG&E	35,522	35,543	7,582,785	743,211	213	21
SCE	76,922	76,922	17,440,307	833,531	227	11
SoCalGas	65,557	100,496	13,281,679	1,267,756	203	13
SDG&E	12,014	9,496	3,073,459	160,282	256	17
Statewide	**190,015**	**222,457**	**41,378,231**	**3,004,781**	**218**	**14**

Source: PA Tracking Data filed with the CPUC

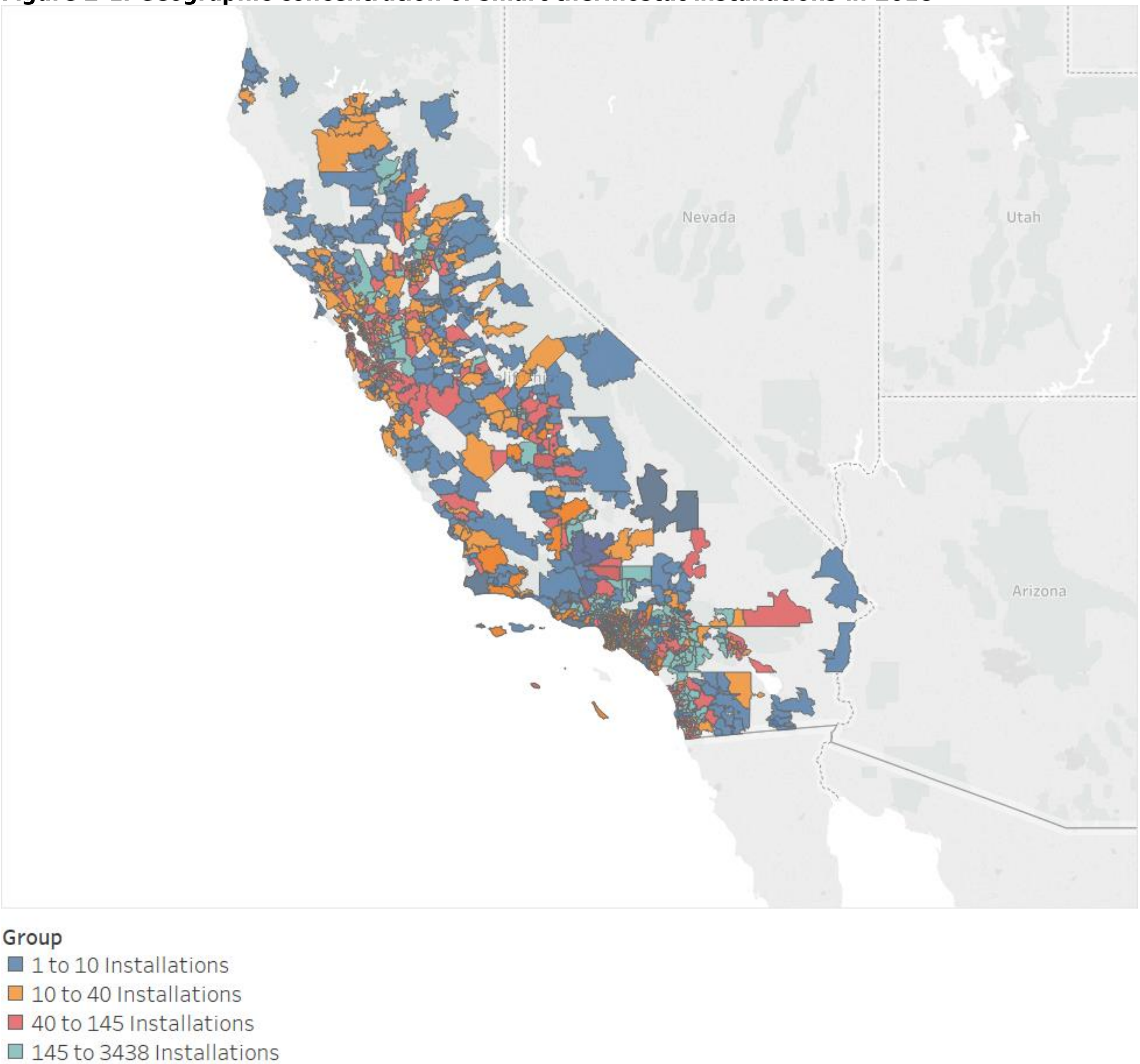
The majority of smart thermostats (60% with kWh savings and 53% with therm savings) were installed in multifamily dwellings through direct install channels (Table 2-3). A quarter to one-third were installed at residential sites that acquired the devices through rebate programs. Another 7% were installed at mobile homes and the remaining were installed in other residential settings under direct install programs. Claimed savings for these devices reflect these general trends.

Table 2-3. Smart thermostat percent installed and claimed savings by program type, PY 2018

Program Type	Percent Households with Electric Savings	Percent Claimed Electric Savings	Percent Households with Gas Savings	Percent Claimed Gas Savings
Residential Rebate	24%	19%	34%	40%
Multifamily Direct Install	60%	59%	53%	49%
Mobile Home Direct Install	9%	12%	7%	4%
Other Direct Install	7%	9%	6%	7%

Figure 2-1 below shows that smart thermostat installation was broad, covering a large part of California, with greater concentration in certain zip codes. This concentration is indicated by a scale provided at the bottom of the map. Program provided smart thermostat installations ranged from 1 per zip code to over 3,000. In program year 2018, smart thermostat installations were most concentrated in zip codes shaded by the light green color.

Figure 2-1. Geographic concentration of smart thermostat installations in 2018



The highest number of smart thermostat installations were in climate zones 10, 9, 8, and 6 (Table 2-4). The normal (typical meteorological year – TMY) cooling and heating degree days (CDD and HDD)[5] for these areas indicate that customers face cooling and heating conditions that are in the middle range for the state. Areas with highest cooling needs in the state have CDD values that are above 2,500 while areas with significant heating needs have HDD values that are above 3,000. Climate zones 6, 8, 9, and 10 experienced an average CDD of 1,400 CDD and HDD of 1,300 in 2018.

[5] Cooling degree days and heating degree days are the number of degrees above or below, respectively, a base temperature such as 65. They are convenient expressions of temperature that correlate well with the amount of energy needed to cool or heat buildings as they begin accruing the approximate temperature at which the houses start to use their heating or cooling system. For instance, if a building starts cooling at an average outdoor temperature of 65 degrees and the average daily temperature on that day is 70, the CDD for that day is the difference between these two values (5). For general comparisons of degree days across geographies, a consistent base of 65 will be used for both CDD and HDD.

Table 2-4. Smart thermostat installation by climate zone, PY 2018

Climate Zone	Normal HDD	Normal CDD	Number of Installations PY 2018
2	3,029	414	1251
3	2,652	299	5186
4	2,458	294	4942
5	2,510	375	687
6	1,391	866	20291
7	1,176	889	6135
8	1,310	982	27444
9	1,566	1,402	42142
10	1,231	1,822	79624
11	2,420	1,873	3026
12	2,398	1,360	13377
13	2,237	2,308	10811
14	1,830	3,109	5767
15	863	4,945	11098
16	2,841	1,771	6066

The majority of program participants installed Nest thermostats, ranging from about 92.9% at SCG to 78.2% at SDG&E. Ecobee thermostats were the next most commonly installed thermostats by program participants followed by Honeywell devices (Table 2-5). These choices reflect workpaper requirements, which prescribe the types of smart thermostats that are eligible for claims, and the bulk purchasing decisions of direct install programs that make the majority of the claims.[6]

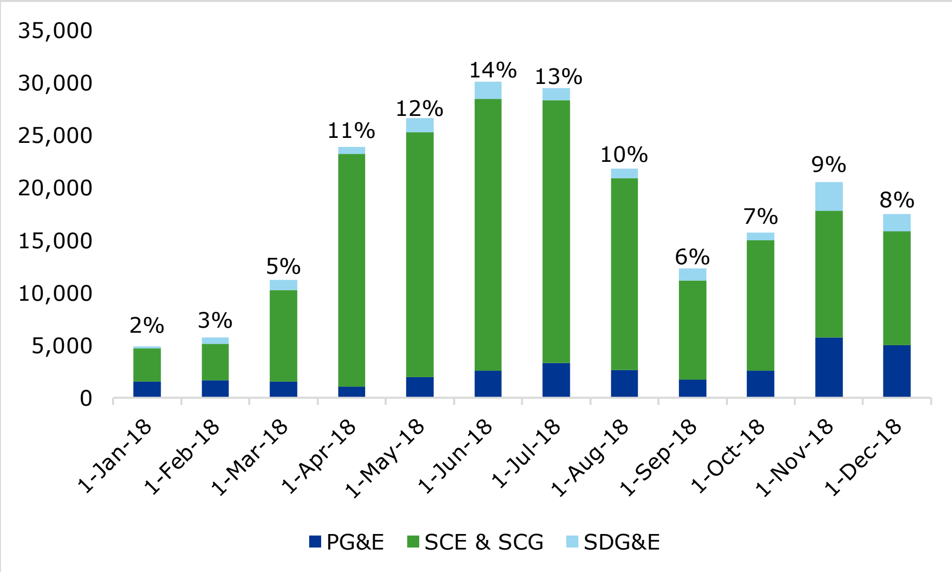
Table 2-5. Smart thermostat models installed by PA, PY 2018

Model	PG&E	SCE	SCG	SDG&E	Statewide
Nest	81.4%	82.6%	92.9%	78.2%	87.4%
Ecobee	14.3%	11.6%	4.8%	21.8%	9.9%
Honeywell	3.5%	5.4%	2.1%	0%	2.4%
Other	0.8%	0.4%	0.2%	0%	0.3%

Smart thermostat installations reflect a strong seasonality regardless of program delivery type. Most customers installed their devices during the summer, with 15% and 14% installations respectively taking place in June and July of 2018 (Figure 2-2). There are also substantial installations during the early winter months. This choice appears to reflect the desire to regulate HVAC use during the primary heating and cooling seasons.

[6] Requirements generally include that devices be two-way communicating and occupancy-sensing. Additional requirements such as schedule learning and capability for weather-enabled optimization are also included.

Figure 2-2. Timing of 2018 smart thermostat installations



2.2 Evaluation objectives

DNV GL's research objectives were to: estimate the electric and gas savings associated with program year 2018 smart thermostat installations; determine the extent to which evaluated savings estimates matched claimed savings; and, estimate free-ridership by measuring which smart thermostat installations would have occurred in the absence of the program. DNV GL also sought to understand program participant characteristics, including dwelling type, location, general demographic background, energy efficiency program participation, and energy consumption behaviors.

3 METHODOLOGY

This section details the approach DNV GL used for the data processing and analysis phases of the smart thermostat evaluation.

3.1 Data sources

DNV GL used the following five sources of data for the evaluation:

- Tracking data: DNV GL sourced information about program participation from tracking data that the PAs filed with the CPUC on the California Energy Data and Reporting System (CEDARS).
- Energy use data: energy consumption data was obtained from the PAs to analyze energy use patterns and changes related to the use of smart thermostats.
- Customer data: Supplementary information on both participating and non-participating customers used in the study was sourced from customer information tables obtained from the IOUs.
- Weather data: Weather data were sourced from the National Oceanic and Atmospheric Administration (NOAA) and Climate Zone (CZ) 2018 to include in regression models accounting for weather sensitivity.[7] CZ2018 are typical meteorological year weather data for select California weather stations that are useful for long-term weather normalization. The study also used climate zone information available by zip code from the CEC.[8]
- Primary research data: The study used data from primary research (survey) to understand customer engagement with the device in order to account for its effect on energy use and to shed light on the impact evaluation results.

DNV GL investigated the feasibility of using device data from thermostat vendors in the evaluation. DNV GL spoke to the 3 major thermostat manufacturers that represented the majority of installations for the PA programs in 2018. All vendors lacked the ability to provide data that could be linked to household and utility energy consumption data and hence there was no clear path to using device data in this impact evaluation. DNV GL is open to working with vendors to see whether there is a way in future evaluations to work with vendor data in compliance acceptable evaluation methodologies.

Table 3-1 summarizes the various sources of data used in the smart thermostat evaluation in program year 2018.

Table 3-1. Data sources used for 2018 Smart Thermostat evaluation

Data	Source	Period Covered	Contents
Tracking Data	CPUC Tracking 2017 and 2018 Data	2017-2018	Program information (IDs, claims)
Program Participant Information	PAs	2018	Program details (devices installed, dates, participant contact info)
Billing Data	PAs	January 2017 - May 2019	Monthly billing data

7 National Oceanic and Atmospheric Administration Hourly Weather Data; California Energy Commission Title 24. https://www.energy.ca.gov/title24/; http://www.calmac.org/weather.asp.

8 https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

Data	Source	Period Covered	Contents
Interval Data	PAs	January 2017 - December 2019	Hourly electric and daily gas data
Customer Data	PAs	2017-2019	Customer location (zip code) and climate zones
Weather Data	NOAA and CZ2018 from CALMAC	January 2017 - December 2019	Actual and TMY3 California weather data

3.1.1 Program participants

The main source of program participant information is the tracking data filed in CEDARS.[9] CEDARS provides all program installations and amount of energy savings these installations are expected to generate.

As noted in section 2.1, smart thermostats were offered by 18 different programs across California's PAs in PY 2018. These programs targeted different population segments and often offered different measure mixes that included smart thermostats. The programs used rebates and direct installation as delivery channels for the smart thermostats they offered. Program tracking data indicates that programs that offered smart thermostats under rebates/incentives include many households that only installed this measure. Direct install programs, on the other hand, generally installed a mix of measures in households they targeted.

For PY 2018 evaluation of smart thermostats, the primary aim was to develop reliable estimates of gross savings per smart thermostat unit. Although the earliest version of smart thermostats was released in the 2010s, smart thermostats are a new program technology, for which evaluation methods have not been refined in prior studies, and for which a default claimed (ex ante) net-to-gross (NTGR) ratio has been assigned. This 2018 evaluation is a first step in establishing methods for this technology and will identify the next level of enhancements to be considered for PY 2019.

For program year 2018 evaluation, DNV GL developed NTGR estimates, derived from occupant and property manager surveys. Participant and property manager survey-based free-ridership estimates were weighted by PA gross savings claims to arrive at final program attribution estimates.

DNV GL estimated gross savings per unit by applying consumption data analysis to households that participated in incentive/rebate programs and installed smart thermostats only. Where multiple measures are installed, consumption data analysis can most reliably provide estimates of whole house savings that occur due to the combination of all the installed measures. Where multiple measures are installed, development of measure-specific savings requires statistical decomposition of whole-house consumption changes into changes due to each measure. Statistical noise and likely multicollinearity make this a challenging undertaking, with the potential that reliable measure-specific estimates may not be possible. A further complication of statistical decomposition of effects of multiple measures is that the incremental effect of a single measure- the smart thermostat -depends on what other measures are also installed.

Thus, for PY 2018 DNV GL analyzed consumption data for smart thermostat savings for homes that installed only this measure, using an incentive/rebate channel. Direct install programs are excluded from the analysis because they are generally designed to provide multiple measures. Homes receiving only smart thermostats under direct install programs are likely to be anomalous because they represent a small subset of the DI programs that want only the smart thermostat while either not wanting or needing the other offerings. This

[9] https://cedars.sound-data.com/

choice makes them less representative of the remainder of DI program participants that accepted some mix of the additional measures.

The consumption data analysis is further limited to individually metered homes. Based on the tracking data provided, the consumption analysis includes individually metered multifamily units as well as single family units.

The consumption data analysis provides gross savings per unit by climate zone. Applying smart-thermostat-only results to applications involving multiple measures, whether incentive or direct install, will likely be somewhat generous, as savings in the program contexts not included in the analysis (multi-measure direct install programs in multi-family and/or manufactured homes) are likely to be lower due to interactions with other measures. DNV GL nonetheless believes that extrapolated results are more reliable than pass-through of ex ante results.

A tracking data assessment revealed that one program from each of PG&E, SCE, and SCG delivered smart thermostats as a stand-alone measure in PY 2018. These were all plug load and appliance rebate programs that allowed customers to claim rebates for qualifying smart thermostats purchased through retailers.[10] SDG&E offered smart thermostats through two different rebate programs. Table 3-2 provides the programs and number of smart thermostats rebated through them as well as the savings claimed for this measure under each program. The thermostats rebated through these programs constitute 24% of total installations with claimed electric savings and 34% of total installations with claimed gas savings.

Table 3-2. Smart thermostat rebate program by PA

Program Name and Administrator	Program ID	Installations with Electric Savings Claims	Installations with Gas Savings Claims	Gross First Year Savings	
				Electric (kWh)	Gas (Therms)
PG&E Residential Energy Efficiency/Plug-Load & Appliance	PGE21002	18,386	18,407	3,018,614	434,225
SCE Plug Load and Appliances Program	SCE-13-SW-001B	7,478	7,478	1,476,366	90,554
SCG Residential Energy Efficiency Program/Plug-Load & Appliance	SCG3702	9,977	41,642	1,976,966	593,205
SDG&E Plug Load And Appliances-Home Energy Efficiency Rebate	SDGE3203	2,181	1,584	337,791	15,927
SDG&E Plug Load And Appliances-Point of Sale Rebates	SDGE3204	7,363	5,442	1,149,565	54,585
Total		**45,385**	**74,553**	**7,959,303**	**1,188,496**

Based on this data, PG&E's Residential Energy Efficiency/Plug-load and Appliance program (program ID PGE21002) included around 18,000 households that were individually metered and installed only a smart thermostat. These were mostly single-family dwellings although about 10% were multifamily. The smart thermostat savings from this program constitute 7% of total first year gross kWh and 14% of total first year gross therm smart thermostat savings from all programs, across PAs and program types.

[10] To be eligible for program rebates, smart thermostats, at minimum, had to be two-way communicating, occupancy sensing, and schedule learning.

SCE's Plug-Load and Appliance program (program ID SCE-13-SW-001B) included about 7,400 households while SCG's Residential Energy Efficiency/Plug-load and Appliance program (program ID SCG3702) provided rebated smart thermostats to about 41,000 households. Interviews with program staff indicated that SCE and SCG offered smart thermostats through a combined rebate promotion and split total rebate payments between them.

Program staff interviews indicated that a sizeable number of rebate claims involved dual-fuel customers. However, the exact numbers involved are not readily apparent as there are no ID maps that identify customers served by both IOUs. For the purpose of estimating savings per households, DNV GL developed a list (a crosswalk) of customers served by both SCE and SCG, which is described in the next section, to identify such customers. Overall, SCE's claimed smart thermostat savings for this program constitute 4% of total first year gross kWh and 3% of total first year gross therm smart thermostat savings from all programs, across PAs and program types. SCG's analogous values were 5% for kWh and 20% for therms.

SDG&E offered smart thermostat rebates through two different programs. Both programs are plug-load and appliance programs, but rebates are made through applications for the first (program ID SDGE3203), while the second one involves a point-of-sale (POS) rebate (program ID SDGE3204). The majority of the claims are from the POS program, and savings from both programs made up 4% of total first year gross kWh and 2% of total first year gross therm savings from all programs, across PAs and program types.

3.1.2 Energy consumption data

Consumption data were obtained from the PAs for both electricity and gas at multiple levels of granularity: billing month, daily, and hourly. Billing data were primarily used as a means of identifying customers who did not get program sponsored smart thermostats (non-participants) and whose energy use patterns can help inform baseline energy consumption. Daily data served to fine-tune the identification of non-participants and serve as the basis for site-level modeling. Additional information on this process is provided in methodology section 3.2. Finally, hourly data were included in models used to estimate the effect of the program/measure on hourly energy demand. Like the other pieces of energy use data, these were also obtained from each PA for program participants and selected non-participants.

Billing data were screened to remove duplicate reads, total zero energy use for the year, and reads that correspond to on-site solar energy production. The billing data were also aggregated to the bill month so that there are 12 reads in a year; billing values that reflect multiple smaller read intervals are summed to the monthly level. Only customers who have a full year of matching period data were then included in the analysis.[11]

Daily data were screened for duplicate reads at the customer and day level, which were then aggregated or removed depending on the context. Customers with on-site solar production were also flagged and removed from the analysis dataset. Finally, only data of customers with a full data from the matching period through the evaluation period were included.

Screening procedures were also used to prepare hourly data for modeling. First, additional households identified as having acquired solar were excluded from the analysis. Households identified as having solar were excluded from the matching because there is no way to determine their true energy consumption given

[11] The full disposition of customer counts used in the analysis is provided in Table 3-3.

the available data.[12] Second, for electricity, aggregated daily energy data missing more than 4 hourly reads were excluded from the analysis. Third, hourly electricity reads that sum to zero for the day were also excluded from the analysis. For both gas and electric customers, only those with at least 90% of daily values in both the pre and post-program period were included for analysis.[13] Finally, the interval data received was checked against billing records to ensure the integrity of the data.

Since there is considerable overlap in the SCE's and SCG's service territory, DNV GL developed a crosswalk to identify the customers the PAs serve jointly. Such an effort was undertaken because program staff interviews revealed that rebate programs were run such that dual fuel customers served by both utilities were required to submit their claims through SCG.

To develop the crosswalk, DNV GL used customer information files that provide premise numbers, addresses, names and phone numbers. While it is straightforward to match addresses and identify a location served by both utilities, identifying customers served by both PAs requires considerable care. DNV GL created the crosswalk with a service site from each IOU that has the same address and whose customer names and phone numbers matched in 2018 customer information tables. DNV GL included electric data from SCG customers identified as being SCE electric customers in the analysis. SCG gas data was also included in the analysis for a small number of electric customers that received rebates through SCE.

The number of customers for whom consumption data were considered and used in the study is provided in Table 3-3. The table indicates starting household counts from the tracking data considered for use in the evaluation; the number of customers without solar and with daily data available for matching, customers with AMI data and 2018 installation dates, and finally customers with AMI data with the requisite pre and post data of at least 328 data available for the analysis. The table provides the breakdown by fuel.

Table 3-3. Smart thermostat customer counts used in the evaluation by PA and fuel type, PY 2018

Customer Data Attrition	SCE Electric	SCG Gas	PG&E Electric	PG&E Gas	SDG&E Electric	SDG&E Gas
Customers in tracking data	7,184	40,987	17,728	17,711	9,536	7,021
Customers installing smart thermostats only	6,952	38,634	16,073	16,089	8,955	6,496
Dual-fuel customer additions (SCE & SCG)	13,175	39,453				
Customers without solar and with daily data used in matching	7,766	23,348	8,557	8,614	6,558	4,579
Customers with AMI data and 2018 installation	7,104	21,285	6,199	6,526	6,424	4,829
Customers with sufficient AMI data used in analysis	5,819	20,182	5,356	6,133	5,102	4,754

[12] Utility records provide net-metered electricity use, which reflects the difference between delivered and received kWh, but not the amount of on-site solar production.

[13] Energy consumption data requirements are in line with CalTrack recommendations. http://docs.caltrack.org/en/latest/methods.html#section-2-data-management

3.1.3 Weather data

Observed and typical meteorological year (TMY) data are important inputs for addressing changing weather conditions and their effect on energy consumption. DNV GL sourced hourly weather data for 82 NOAA weather stations across California that provide historical weather observations and for which TMY series were developed (CZ2010 and, more recently, CZ2018). CZ2018 are typical meteorological year weather data for select California weather stations that are useful for long-term weather normalization. They are provided on California's Measurement Advisory Council site and update the 2010 typical year weather data to reflect more recent weather trends.[14]

DNV GL applied the following data filtering protocols, in line with CalTrack recommendations, and used weather data from 59 weather stations that have complete and usable data for the analysis.[15] These include:

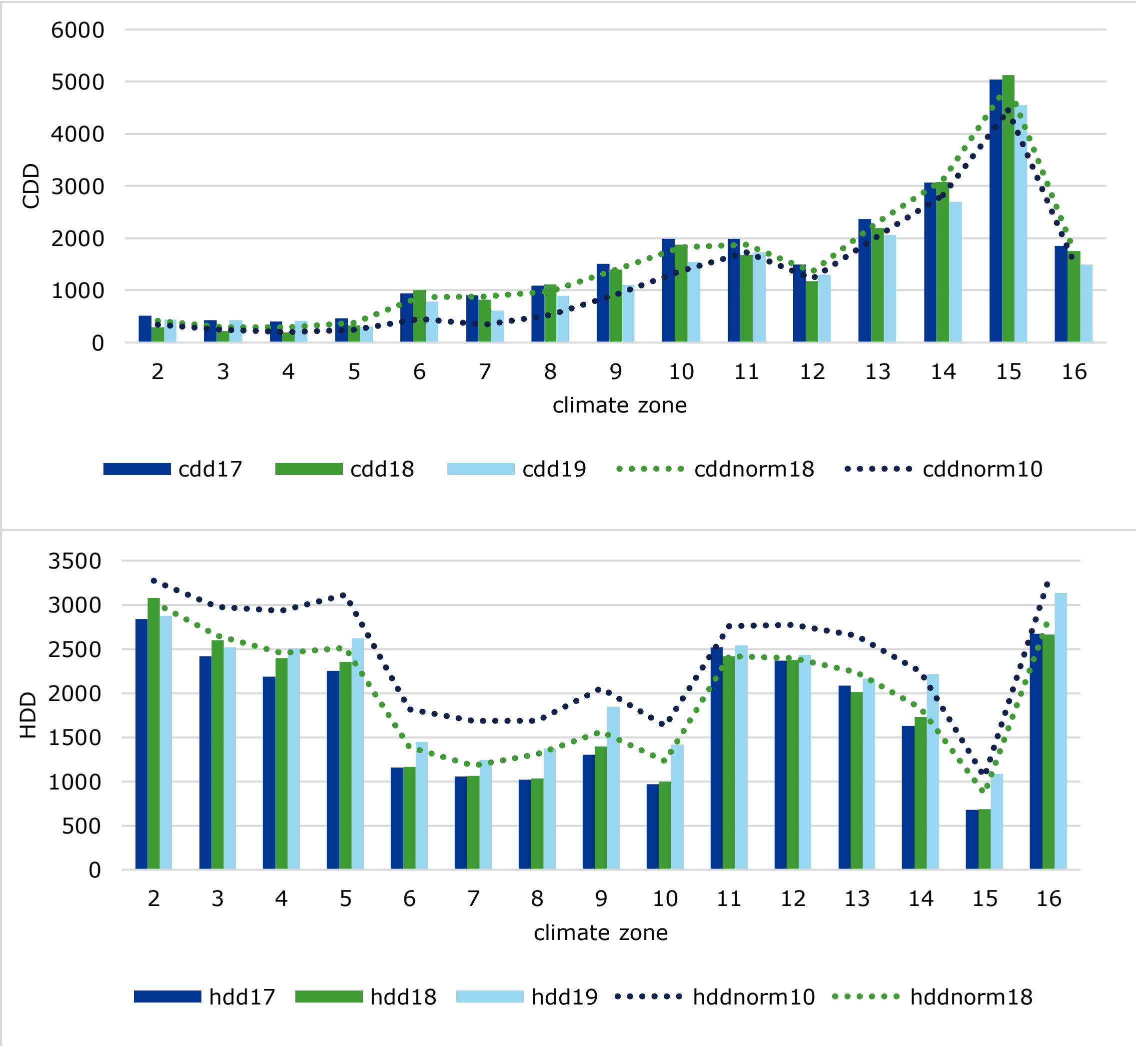
- Interpolated gaps for up to 6 consecutive hours
- Used only daily average data for days missing no more than 12 hourly temperature reads
- Used data from stations that have at least 90% of the data for each year needed in the analysis

Figure 3-1 provides a summary of the weather data for cooling degree-day (CDD) and heating degree-day (HDD) used in the study. DNV GL used 2018 TMY instead of 2010 TMY data to weather normalize consumption in this study. The 2018 values reflect more recent weather patterns including warmer summers and more mild winters. The figures also indicate that the actual weather cooling degree days during 2017 and 2018 did not deviate significantly from CZ2018 normal weather cooling degree days. Cooling degree days were lower in most CZs in 2019. Actual weather heating degree days were more variable across the three years and climate zones, though in all cases degree days were distributed around the CZ2018 normal weather. In general, weather normalization controls for the effect of such weather variation by putting energy consumption on the same normal weather terms across time. In addition, the figure illustrates areas of the PAs service territories that have significant cooling needs (climate zones 13 through 15) and heating needs (climate zones 2 through 5 and 16).

[14] http://calmac.org/weather.asp

[15] http://docs.caltrack.org/en/latest/methods.html#section-2-data-management

Figure 3-1. Summary of weather data



3.1.4 Survey data

DNV GL surveyed participants, non-participants, property managers, and contractors to inform program attribution and provide data that helps to characterize participants and non-participants in terms of program exogenous characteristics that provide context to savings estimates.

3.1.4.1 Occupant surveys

DNV GL administered **participant surveys** to customers who are the decision makers for smart thermostat installations in their households and availed themselves of a **program rebate** for these installations (participated in smart thermostat programs). The primary objective of these surveys is to inform estimates of free-ridership (and the complementary NTGRs or program attribution estimates). Surveys also gather information on thermostat use, satisfaction, energy use behavior, and demographics from both participants and non-participants.

DNV GL also surveyed **non-participant** customers from the matched-comparison group that support the billing analysis. The matched comparison households are a set of customers who have been matched to the participants based on their energy consumption patterns, but who have not participated in smart thermostat programs. The primary objective of the non-participant surveys is to provide a reference point related to demographics and energy use behavior.

3.1.4.2 Property manager surveys

The majority of smart thermostats (60% with kWh savings and 53% with therm savings) were installed in multifamily dwellings through direct install channels. Direct install programs provide customers with smart thermostats **free of cost**. For most smart thermostats installed through direct install programs, property managers are the decision makers responsible for smart thermostat installations for several customers residing in that property. DNV GL surveyed property managers to inform free-ridership estimates for direct install programs where property managers are the decision makers.

3.1.4.3 Contractor surveys

DNV GL surveyed contractors to obtain an additional estimate of free-ridership and program attribution for direct install programs where the occupant is not the decision maker. While the final program attribution estimates represent a blend of estimates derived from participant and property manager surveys, contractor free-ridership estimates represent a verification check of the NTGRs derived from the occupant and property manager surveys used to arrive at net savings.

3.2 Measure savings

3.2.1 Gross savings

This evaluation takes a two-stage modeling approach to estimate the effect of smart thermostats on energy consumption. The approach uses variable degree-day PRISM-inspired, site-level models with a matched comparison group in a difference-in-difference (DID) framework. This is a well-established and accepted methodology that is appropriate for the evaluation of energy changes at the home level after energy efficiency intervention.

The two-stage approach has a long track record in energy program evaluation and is effectively the basis for current methods developed for new pay-for-performance programs in California and beyond. The methodology is attractive for a variety of reasons including:

- Site-level focus
- Full use of weather information at the daily level
- Use of a comparison group as a proxy for non-program-related change
- Separation of the weather-normalization process from savings estimation

The methodology is also consistent with the approach laid out in the Uniform Methods Project (UMP) Chapter 8 modeling approach, which provides whole-house savings estimation protocols for energy efficiency interventions that have whole-home impacts like smart thermostats.[16] The modeling approach is also closely related to all other forms of program analysis that use energy consumption data including time-series, cross-

[16] Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol. The Uniform Methods Project. https://www.nrel.gov/docs/fy17osti/68564.pdf

section approaches. Finally, it is also consistent with CalTRACK, the recent effort to develop agreed upon steps for the site-level modeling portion of the analysis.[17]

The two-stage approach relies on the comparison group to control for non-program, exogenous change. To do this, the approach assumes that the comparison group is a reasonable proxy for the counterfactual of the participant group. The intent of matching as a basis for choosing a comparison group is to develop a group that has similar characteristics and can serve this purpose. However, though matched on pre-period consumption and various other characteristics, the approach still must assume that participant and comparison groups have similar underlying trends over time. To the extent there are differential underlying trends, the savings estimates may be biased up or down. The comparison group may over- or under-compensate for the trend in participant consumption over time, over- or underestimating savings in the process. There are no accepted alternatives to this quasi-experimental design approach for this kind of after-the-fact (opt-in) evaluation of a rebate program.

The first stage of the approach uses weather data to set energy consumption pre- and post-intervention on equal weather footing to isolate the effect of the intervention from weather effects. The second stage model uses a quasi-experimental method, the best and only option in the absence of a randomized experimental design, to control for non-program related changes.

3.2.1.1 Site-level modeling

DNV GL used a widely applied method based on the PRISM approach to weather-normalize electricity and gas consumption at the individual site level. Weather-normalization makes it possible to determine trends in energy use based on typical or normal weather, effectively removing the impact of yearly weather fluctuations on energy use. The method involves estimating a set of regression models of energy use as a function of weather. The regression model is given by:

$$E_{im} = \beta_0 + \beta_h H_{im}(\tau_h) + \beta_c C_{im}(\tau_c) + \varepsilon_{im}$$

Where:

E_{im} - Average electric (or gas) consumption per day for participant i during period m.

$H_{im}(\tau_h)$ - Heating degree-days (HDD) at the heating base temperature reference temperature, τ_h.

$C_{im}(\tau_c)$ - Cooling degree-days (CDD) at the cooling base temperature, τ_c, (not included in gas models).

$\beta_0, \beta_h, \beta_c$ – Site-level regression coefficients measuring intercept (base load), heating load, and cooling load, on a single year's energy consumption, respectively.

τ_h - Heating base temperatures, determined by choice of the optimal regression.

τ_c - Cooling base temperatures, determined by choice of the optimal regression.

ε_{im} – Regression residual.

Consumption is estimated over a range of 64°F to 80°F for cooling and 50°F to 70°F for heating to identify the temperature base points for each site (household); statistical tests identify the optimal set of base points. The site-level models produce parameters that indicate the level of energy consumption not correlated with either HDD or CDD (baseload), and the levels of energy consumption correlated with HDD (heating load) or CDD (cooling load). DNV GL estimated site-level models using daily data. First-stage models were screened to remove estimates that had implausible (negative) cooling and heating coefficients.

[17] CalTRACK, http://www.caltrack.org/

Model parameter estimates for each site allow the prediction of site-level consumption under any weather condition. For evaluation purposes, all consumption is put on a typical weather basis, using CZ2018 TMY values, and produces an estimate referred to as normalized annual consumption (NAC). NAC for the pre- and post-installation periods are calculated for each site and analysis time frame by combining the estimated coefficients $\hat{\beta}_h$ and $\hat{\beta}_c$ with the annual typical meteorological year (TMY) degree days H_0 and C_0 calculated at the site-specific degree-day base(s), $\hat{\tau}_c$ and $\hat{\tau}_h$. NAC is given by:

$$NAC_i = (365 \times \hat{\beta}_0) + \hat{\beta}_h H_0 + \hat{\beta}_c C_0$$

Individual household level regression models are estimated using observed weather data from the NOAA sites. Associated TMY data are used to weather normalize annual consumption using the estimated model parameters. The process serves two purposes; first, putting pre- and post-installation consumption on the same weather basis so that change in weather is not conflated with program effect, and, second, choosing a weather basis that represents a reasonable expectation of future weather for the ex ante projections.

3.2.1.2 Difference-in-difference modeling

Normalized annual consumption from site-level models form the basis for the second stage of the analysis. A model based on the pre-to-post difference in NAC for participant households and a matched comparison group is estimated using a difference-in-difference modelling approach. This model is given by:

$$\Delta NAC_i = \alpha_0 + \beta T_i + \varepsilon_i$$

In this model, i subscripts a household and T is a treatment indicator that is 1 for smart thermostat households and 0 for the matched comparison homes. The effect of the program is captured by the coefficient estimate of the term associated with the treatment indicator, $\hat{\beta}$.

Pre- and post-program periods are based on a definition of a blackout period for each participant. According to CalTRACK, an intervention period is a "time between the end of the baseline period and the beginning of the reporting period in which a project is being installed." It advises the use of "the earliest intervention date as project start date and the latest date as the project completion date."[18]

Based on the CalTRACK recommendation and the IOU-provided tracking data, DNV GL defined a blackout period that reflects installation months reported in the tracking data. All the sites used in this evaluation indicate a single installation date. These installation dates are used to define the blackout period. DNV GL tested blackout periods that included the month of installation and 2 months before, and the month of installation and two months after installation but did not find savings estimates that varied significantly.

Pre- to post-installation changes in weather normalized energy use that exceed plus or minus 50% are likely due to other changes in the home and not smart thermostat use. DNV GL considered these to be outliers and excluded them from the second-stage DID models.

3.2.1.3 Matched comparison group construction

The matched comparison group forms the foundation of the experimental design used in this study. This quasi-experimental set up is commonly used to construct a comparison group for the purposes of generating a counterfactual when randomized control trial (RCT) is either not feasible or not used. In this evaluation, there are three matching phases undertaken to identify matched comparison groups used to estimate the impact of smart thermostats on energy use.

[18] http://docs.caltrack.org/en/latest/methods.html#section-2-data-management

Phase 1: DNV GL used propensity score matching (PSM) as an initial filter to identify 10 matched comparison candidates for each participant household from the population of each PAs' energy customers. PSM uses propensity scores, which measure probabilities that subjects are assigned to the treatment group given certain characteristics they have, to select candidate comparison customers. This stage of the comparison group construction was a screening process that allowed the identification of 10 customers that served as potential final matches for each participant. The propensity score process used 12 monthly pre-installation (2017) gas and/or electric values within CEC defined climate zones for each fuel type. For dual-fuel customers both gas and electric values were included in the matching process.

Phase 2: DNV GL then requested more granular data for participants and their 10 matched comparison households from the initial matching process for use in phase 2 matching. The data requested reflected information on household energy use both in typical and extreme conditions. For electric customers, these included daily average, 6:00 p.m., and minimum and maximum kWh reads, while for gas customers these included daily average therm reads.

For both electricity and gas, matching in this phase was based on weekday and weekend average monthly reads that were calculated to capture seasonal energy use shapes. DNV GL used an additional step for electricity matching to capture peak demand conditions. This involved the identification of the weekday in each of June through September where most customers had their maximum 6 p.m. kWh reads and including 6 p.m. kWh reads from those days in the matching.

Twenty-four electric kWh values, reflecting average weekday and weekend daily use for each month, and four selected summer 6:00 p.m. kWh reads were used to match electric customers. For gas customers, analogous 24 gas therm values for each day type and month were used in the matching. DNV GL used PSM based on these data to obtain one match for each participant (1:1 matches) by fuel and climate zone for each PA.

Phase 3: DNV GL requested and received hourly kWh and daily therm values for the selected 1:1 participant and comparison households matched in phase 2. In order to maintain balance for the selected 1:1 matches, a third and final phase of matching by fuel and climate zone was undertaken using these data. For this phase, DNV GL used total annual kWh and the ratio of summer-to-winter energy for matching as these two metrics summarized the condition of energy use sufficiently well. Based on these metrics, DNV GL used Mahalanobis matching with replacement to prepare the final matched comparison dataset used in the analysis.

Test of balance: For each phase of matching, tests of balance were conducted to test the condition of matching. The tests involved a comparison of the empirical distribution of matching variables via plots of their distribution, and the evaluation of their standardized mean differences and the ratio of their variances for the matched groups. The standardized mean difference is given by:

$$d = \left(\bar{X}_{treatment} - \bar{X}_{comparison}\right) / \sqrt{\left(S^2_{treatment} + S^2_{comparison}\right)/2}$$

A standardized mean difference value that exceeds 0.2 shows extreme imbalance, while the closer to 0 this value gets, the better the condition of matching. For the variance ratio, a value close to 1 indicates balance while values that are 0.5 or less and 2 or greater indicate extreme imbalance.[19]

[19] Details of these tests are provided in http://www.iepec.org/2017-proceedings/65243-iepec-1.3717521/t001-1.3718144/f001-1.3718145/a011-1.3718175/an042-1.3718177.html

3.2.2 Program attribution

We examine how successful the PA programs were in influencing program participants to install smart thermostat that would not have been installed if the programs had not existed. Participants that would have installed the same smart thermostats in the absence of the program are considered free riders. They are referred to as free riders because they are receiving incentives from the programs for actions they would have undertaken without the program's existence. The total amount of savings derived among all participants, including free riders, is referred to as "gross savings," and the savings that is generated without free riders is "net savings".

We develop estimates of the ratio between the net and gross levels of savings (the net-to-gross ratio or NTGR). A ratio equal to 100% or 1.0 means the PA-sponsored program completely influenced smart thermostat installation and anything less than one indicates the level of free ridership; for example, 25% free ridership would yield a (ratio) of 0.75.

DNV GL surveyed **participants and property managers** who were decision makers for direct install programs targeting multifamily properties as well as **contractors** who delivered smart thermostats to customers, to determine the level of free-ridership and program activity that could be attributed to the program incentives.

DNV GL's approach focuses on assessing 3 dimensions of free-ridership: timing, quantity, and efficiency. Taken together, these dimensions allow for estimates of net energy (kWh) savings attributable to the measure, because that energy is a factor of the number of measures installed (quantity), the efficiency of the measures (efficiency), and the duration that the measures are installed (timing).

The various PA-delivered programs that provided smart thermostats to residential customers gave rebates for just **one smart thermostat installation per household**. Free-ridership surveys for smart thermostats thus require a modification to this approach and do not include the quantity dimension. It should be noted that in the context of direct install programs, where DNV GL surveyed property managers and contractors, quantity is applicable because it represents the number of smart thermostats installed through the program. This leaves timing and efficiency, which are still applicable in both the rebate and direct install program contexts.

Survey question responses on the timing and efficiency of the installations are scored using an algorithm to arrive at free-ridership and program attribution estimates. The surveys also include a question about the overall likelihood of installation absent program incentives that serves to verify the estimated free-ridership. The details of the algorithm used to determine program attribution are summarized in Appendix J: NTG survey scoring. Section 4.2.1 presents program attribution estimates for the smart thermostat evaluation.

3.3 Load savings shapes

Estimates of energy savings (kWh and therms) provide how much energy savings occur from the use of smart thermostats. These provide answers to 'what' the program achieves. In order to understand 'when' these savings occur, DNV GL examined the load savings shapes from the measure for each PA. Load savings shapes identify the hourly load savings available from the program over the course of the year (for all 8,760 hours in the year) or for an average 24 hour period over the whole year or by season. This identifies periods of the year or the day during which smart thermostat savings occur. DNV GL provides average hourly load savings shapes over the whole year and by season for each PA.

Such load shapes are based on customer or site-level regressions and difference-in-difference models. The site-level regressions are used to produce separate annual hourly load shapes for treatment and control group customers. The estimated hourly load shapes are then used in difference-in-difference models to generate hourly load savings shapes 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 = HDD and CDD values from a specified or optimal 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 optimal base temperatures used in the CDD and HDD values in the hourly load regressions are derived from similar site-level models based on average daily energy use and a PRISM model grid search over CDD and HDD degree day values. These 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. Such optimal heating and cooling reference temperatures or optimized bases are 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:

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

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

$\dddot{H}_o$, $\ddot{c}_o$ = TMY/CZ2018 heating and cooling degree days from base used in regression.

DNV GL applied this model to a full year of hourly data in both the pre- and post-installation periods for each PA. The models used data from both treatment and comparison groups and provide predictions of consumption for all hours of the year based on TMY/CZ2018 weather data.

Predicted consumptions for all hours from the pre- and post-period were used in a difference-in-difference regression to produce hourly load savings shapes. 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.[20] 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

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

$Y_h^{part,pre}$ = 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 used this approach to decompose hourly load shapes and savings into baseload, heating and cooling load. These load savings shapes are considered for the average hour for the year and by season.

4 SURVEY

4.1 Survey approach

DNV GL surveyed program participants (occupants and property managers), program implementation contractors, and occupants who did not participate in the programs, referred to as non-participants. The primary survey objective was to develop attribution factors for estimating free-ridership. The survey data also provide information to identify and understand any trends observed in the results from factors outside the program. This includes participant demographics, dwelling characteristics, as well as changes in energy usage behavior.

The non-participant survey serves as a point of comparison with respect to thermostat use and any self-reported changes in the household that are separate from the program. We also conducted surveys among property managers who are the decision makers for installations in the case of direct install programs that serve multifamily properties. The complete surveys are provided in Appendix L: Surveys. Topics covered by the participant, non-participant, and property manager surveys are summarized below (Table 4-1).

Table 4-1. 2018 Smart thermostat survey topics – participants, non-participants, and property managers

Survey topic	Participants	Matched Non-participants	Property Managers
Acquisition/installation year	x	x	x
Rebate received	x		x
Brand installed	x	x	x
Channel through which became aware of the smart thermostat rebate	x		x
Free-ridership questions (overall likelihood, timing, and efficiency)	x		x
Total number of thermostats in the home	x	x	
Smart thermostat experience influencing additional smart thermostat purchases	x	x	
Type of thermostat installed previously in the home	x	x	x
Previous and current smart thermostat use	x	x	x
Use of smart thermostat mobile app	x	x	
Winter and summer thermostat set-point	x	x	
Comfort post-installation of smart thermostat	x	x	
Satisfaction with the thermostat	x	x	~~x~~
Participation in DR and EE programs	x	x	
Smart energy offer adoption (Smart LEDs, Smart appliances, Home hub, Battery Storage, TOU rates, Auto bill pay, Electronic bills)	x	x	
Changes to home, appliances, energy usage behavior	x	x	
Dwelling characteristics (dwelling type, square footage, heating fuel type, cooling system)	x	x	x
Demographics (home ownership. household size, income)	x	x	

Contractor surveys provided an additional estimate of free-ridership/program attribution for direct install programs where the occupant is not the decision maker. While the final program attribution estimates used in this evaluation represent a blend of estimates derived from participant and property manager surveys, contractor free-ridership estimates represent a consistency check that helps triangulate the NTGRs used to arrive at net savings. The complete surveys are provided in Appendix L. Topics covered by contractor surveys are summarized below (Table 4-2).

Table 4-2. Smart thermostat contractor survey topics

Contractor Survey topic
Service: Offered smart thermostats before the program
Sell smart thermostats outside the program If no, why not?
If program incentive ended, would you offer smart thermostats, If yes, why wouldn't you offer the services
Sales Practices: Involved in direct marketing to identify customers If yes, how do you enlist them? If yes, how do you market outside the program?
Attribution: In 2018 you installed a total of X smart thermostats through PA programs. If the programs had not been available, approximately what % of those installations would you still have provided in 2018? Why do you say that?
Satisfaction What aspects went well? What could be improved?

4.1.1 Survey mode and sample disposition

Participant and non-participant occupant surveys. DNV GL administered web surveys among participants and matched non-participants over an approximate 10-week period from November 2019 to January 2020. The sample frame for participant surveys were customers who had received rebated thermostats in PY 2018. The sample frame for non-participant surveys is drawn from the set of matched comparison households used in the billing analysis used to estimate savings. Matched comparison households are a set of non-participants who have been matched to the participants, post-hoc, based on their energy consumption patterns.

DNV GL attempted a census approach and included all customers with available email contact information and who were not on the PAs' do-not-contact list in the final survey sample frame. Respondents were incentivized to participate in the survey and offered a $100 lottery incentive to complete the survey. Survey invitees were encouraged to complete the participant and non-participant surveys and two reminders were sent through the survey fielding period.

The surveys included both CPUC and IOU branding to boost customer response. The survey also included a link to a dedicated page on the CPUC website that allowed respondents to validate the sponsor and the legitimacy of the surveys. The sample disposition for the occupant surveys of participants and non-participants is summarized in Table 4-3.

Table 4-3. Sample disposition for participant and non-participant surveys

Occupants (Participants)	PG&E	SCE	SCG	SDG&E
Invites sent	15,944	11,647	34,277	11,107
Click-through	5,255	2,625	5,762	2,836
Incomplete	494	227	566	252
Completed	3,865	1,854	4,102	2,041
Response rate	24%	16%	12%	18%
Occupants (Non-Participants)	**PG&E**	**SCE**	**SCG**	**SDG&E**
Invites sent	4,564	2,419	13,641	3,726
Click-through	666	425	1,396	467
Incomplete	57	17	119	39
Completed	484	307	1,042	336
Response rate	11%	13%	8%	9%

Property manager surveys. DNV GL administered property manager surveys for installations where property managers served as the primary point of contact. DNV GL used a mixed-mode approach to administer property manager surveys. Due to poor response to the web surveys, non-respondents were subsequently contacted to complete the survey by phone. Calls were placed over an approximate 4-week period beginning in late December 2019 through mid-January 2020. The sample frames were a census of PY 2018 properties that received rebated or no cost thermostats. Similar to the participant and non-participant surveys described above, DNV GL offered a $100 lottery style incentive for assistance in completing the survey. The sample disposition for the property manager surveys is summarized below (Table 4-4).

Table 4-4. Sample disposition for property manager surveys

Property Managers	PG&E	SCE[21]	SDG&E
Invites sent	67	21	43
Incompletes	1	0	2
Completed	26	21	24
Response rate	39%	100%[22]	56%

Contractor surveys. DNV GL administered surveys among contractors that implemented smart thermostat installations in multi-family housing, manufactured homes, and mobile homes for the PAs' direct install programs. The majority of contractors' smart thermostat installations were in multifamily properties.

The sample frame for contractors was all installation contractors and DNV GL adopted a census approach to complete these interviews. Due to the small population of implementation contractors, all interviews were completed by telephone. Several contractors operate across the state and helped to deliver smart thermostats for multiple PAs. The main objective of the contractor surveys was to provide an additional

[21] SCE and SCG jointly deliver smart thermostats through their programs and the property manager surveys conducted above for SCE also apply to SCG.

[22] Where properties span multiple campuses operated by the **same firm**, a complete with a property manager at one of the properties counts as a complete. The survey confirmed that free-ridership derived from these property managers applied to all properties that were managed under the umbrella of that firm.

estimate of free-ridership and program attribution. The sample disposition for the contractor surveys is summarized below (Table 4-5).

The contractors interviewed represent 69% of all smart thermostat installations for direct install programs for PY 2018. The interviews completed represented the full range of firm size, and included firms like Synergy, Proctor Engineering, and American Power Solutions that were responsible for over 10,000 smart thermostat installations each and also with firms responsible for fewer installations like Honeywell, Utility Incentives Corporation that installed fewer than 5,000 each.

Table 4-5. Sample disposition for contractor surveys

Contractors	All PAs
Invites sent	23
Completed	12
Response rate	52%

4.1.2 Sample weights

DNV GL applied sample weights in order to balance participant and non-participant survey samples to population proportions by PA, fuel type, climate zone category, and consumption level combination. Details of the weighting procedure may be found in Appendix K.

Participant survey sample weights. No trimming of weights was required with the minimum weight, maximum weight, and the ratio of the maximum to minimum sample weight at 0.5, 1.8, and 3.7 respectively.

Non-participant survey sample weights. No trimming of weights was required with the minimum weight, maximum weight, and the ratio of the maximum to minimum sample weight at 0.7, 1.9, and 2.8 respectively.

Property manager sample weights. Sample weights were applied to balance property manager survey samples within each PA by the level of savings claims. Therefore, property managers who installed a greater number of smart thermostats count commensurately toward the final property manager free-ridership score.

Contractor survey sample weights. Contractor survey responses were weighted by the number of smart thermostat installations they implemented to arrive at the contractor free-ridership score. Therefore, contractors who installed a greater number of smart thermostats count commensurately toward the final contractor free-ridership score.

Overall, the primary research conducted for this evaluation had balanced survey samples requiring minor corrections for over and under representation thus reducing the design effect on the data and any potential inflation of standard errors for estimated statistics.

4.2 Survey results

4.2.1 Free-ridership and program attribution

The central objective of the smart thermostat surveys was to capture participants' self-reported responses that provide information on free-ridership and allow estimation of NTGRs that are then used to adjust gross savings estimates. This self-reported approach involved asking program participants a series of questions that were aimed at establishing if smart thermostats would have been installed in the absence of program incentives, and if so, the extent to which the installation might have differed in the absence of the program in terms of timing of the installation and efficiency of the smart thermostat. Program incentives for smart thermostats range from a rebate of $50 to $75. Customers served through direct-install programs receive the smart thermostats for free (100% rebate).

Property manager surveys inform free-ridership estimates in the case of direct install programs where the property manager is the decision maker for multiple smart thermostat installations rather than the occupants in the individual households receiving smart thermostats. In the case of the rebate programs, participant surveys with occupants inform free-ridership. The details of the free-ridership scoring algorithm used is provided in Appendix J: NTG survey scoring. Participant and property manager survey based free-ridership estimates are weighted by PA gross savings claims to arrive at final program attribution estimates (Table 4-6).

As expected, the surveys reveal lower levels of free-ridership and higher program attribution for direct install programs relative to rebate programs at 73% - 95% versus 43% - 57%. Program attribution for direct install programs delivered by implementation contractors is estimated at 96% based on the contractor surveys. This is consistent with program attribution estimates that range from 92% to 95% for direct install programs based on the property manager surveys.

Table 4-6. Program attribution (NTG) by PA program, delivery mechanism, and survey

Program ID	Program Name	PA Gross Savings Claims - kWh	Weight	Delivery Mechanism	Survey	NTG	
PGE210011	Residential Energy Fitness program	667,896	9%	Direct install	Participant	85%	70%
PGE21002	Residential Energy Efficiency/Plug-Load & Appliance	3,018,614	40%	Rebate	Participant	43%	
PGE21009	Direct Install for Manufactured and Mobile Homes	829,063	11%	Direct install	Participant	81%	
PGE21008	Multifamily Enhance Time Delay Relay (Cooling Optimizer)	3,067,212	40%	Direct install	Property Manager	91%	
SCE-13-SW-001B	Plug Load and Appliances Program	1,476,366	8%	Rebate	Participant	46%	84%
SCE-13-SW-001G	Residential Direct Install Program	3,080,040	18%	Direct install	Participant	75%	
SCE-13-TP-001	Comprehensive Manufactured Homes	1,972,916	11%	Direct install	Participant	73%	
SCE-13-SW-001C	Multifamily Energy Efficiency Rebate Program	10,910,985	63%	Direct install	Property Manager	94%	
SCG3702	RES-Residential Energy Efficiency Program	1,976,966	16%	Rebate	Participant	51%	84%
SCG3762	RES-CLEO	14,112	0%	Rebate	Participant	51%[23]	
SCG3765	RES-Manufactured Mobile Home	1,783,593	14%	Direct install	Participant	82%	
SCG3704	RES-MFEER	8,612,653	70%	Direct install	Property Manager	94%[24]	

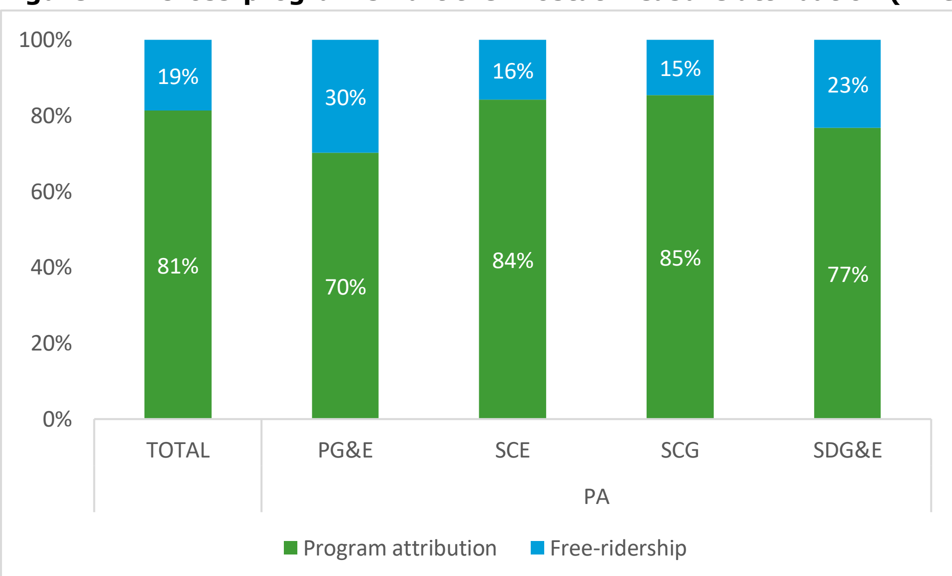
[23] The NTG estimate for the RES-CLEO program (SCG 3762) is imputed with the value of the NTG estimate for the Residential Energy Efficiency Program (SCG 3702) as the former program has too few observations in the survey to derive a free-ridership estimate specific to that program.

[24] The NTG estimate for SCG's MFEER program is the same as the NTG estimate for SCE's MFEER program as these are delivered jointly to multifamily properties served by both PAs.

Program ID	Program Name	PA Gross Savings Claims - kWh	Weight	Delivery Mechanism	Survey	NTG	
SDGE3203	SW-CALS-Plug Load and Appliances-HEER	337,791	9%	Rebate	Participant	51%	77%
SDGE3204	SW-CALS-Plug Load and Appliances-POS Rebates	1,149,565	30%	Rebate	Participant	57%	
SDGE3211	Local-CALS-Middle Income Direct Install (MIDI)	58,495	2%	Direct install	Participant	86%	
SDGE3279	3P-Res-Comprehensive Manufactured-Mobile Home	520,631	14%	Direct install	Participant	75%	
SDGE 3207	SW-CALS-Multifamily Energy Efficiency Rebate	1,783,593	46%	Direct install	Property Manager	95%	

DNV GL estimated free-ridership of 19% based on residential program participant (occupant) and property manager surveys (Figure 4-1). While program attribution (NTG ratios) varies by PA, approximately 81% of overall smart thermostat savings are directly attributable to the program.

Figure 4-1. Cross-program smart thermostat measure attribution (NTG) and free-ridership



4.2.2 Demographic profile of participants and non-participants

In addition to informing the proportion of savings the program should get credit for, surveys also provide relevant information on customer characteristics related to energy consumption. DNV GL surveyed participants and non-participants i.e. customers who did not receive program discounted or free smart thermostats. These non-participants are a select subset chosen for their resemblance to participants in terms of their total energy consumption. Table 4-7 below presents a survey-based demographic profile of the non-participants and participants below. It also includes a comparison of direct install and rebate program participants. Shaded cells represent significant differences between participants and non-participants, and between participants receiving or installing smart thermostats through direct install and rebate program delivery channels.

Higher proportions of participants tend to be homeowners, reside in newer and larger homes, have central air conditioning, and have higher incomes. Participants also reported installing energy efficiency upgrades such as water-saving aerators, duct test and sealing, and fan motor upgrades in marginally higher proportions than non-participants.

As expected, direct install participants have a higher proportion of apartments relative to rebate participants. They also report installing energy-efficiency upgrades such as water-saving aerators, duct test and sealing, and fan motor upgrades in significantly higher proportions than rebate participants. This is a function of the fact that these efficiency upgrades were commonly installed as part of a direct install package. Rebate participants are more affluent and live in larger homes compared to direct install participants.

Table 4-7. Demographic profile of all non-participant and participant survey respondents

	Non-Participants (n=2,407)[25]	All Participants (n=10,151)	Direct Install Participants (n=1,254)	Rebate Participants (n=8,897)
Home ownership	84%	92%	92%	92%
Dwelling Vintage				
Before 1979	59%	43%	26%	45%
1980-1999	24%	29%	35%	28%
2000 and after	18%	28%	40%	27%
Dwelling Size				
Less than 1,000 square feet	12%	5%	5%	5%
1,000 to less than 2,000 square feet	49%	55%	58%	54%
Greater than 2,000 square feet	35%	38%	34%	39%
Dwelling Type				
Single-family home	80%	80%	76%	80%
Townhouse, duplex	8%	10%	2%	11%
Apartment, mobile home, other	12%	10%	22%	9%
Main Heating Fuel				
Natural gas	83%	85%	83%	85%
Electricity	12%	11%	12%	11%
Other	4%	4%	5%	4%
Main Cooling System				
Central air conditioner	74%	85%	89%	85%
Other	14%	13%	10%	14%
I don't have a cooling system	12%	1%	1%	1%
Energy Efficiency Upgrades Installed				
Water saving aerators	9%	11%	22%	9%
Duct test and sealing	6%	8%	17%	7%
Evaporative fan motor upgrade	1%	2%	9%	1%
Pool pump	6%	6%	4%	6%
Income				
Less than $50,000	16%	9%	34%	6%

[25] Sample sizes for each question varies and is approximately equal to numbers listed above. Questions and response options are as shown in the full surveys included in Appendix L.

	Non-Participants (n=2,407)[25]	All Participants (n=10,151)	Direct Install Participants (n=1,254)	Rebate Participants (n=8,897)
$50,000 - $100,000	22%	18%	26%	16%
Greater than $100,000	37%	48%	21%	52%

4.2.3 Changes in home impacting energy use

Respondents were asked to indicate whether they had made any changes in their home since 2018. These changes related to EV charging, refrigerator use, household size, living area, pool use, spa use, and lighting use which could have an impact on energy use. Respondents could indicate changes that could have resulted in either an energy use increase or decrease. For example: When asking about refrigerator use, customers could indicate that they were **using an additional refrigerator** or that they got **rid of/recycled/stopped using an additional refrigerator**. A comparison of net energy use increasing actions[26] between non-participants and participants is presented below in Table 4-8. We also contrast customers that received smart thermostats for free through direct install programs against those that availed themselves of rebates through the incentive programs. Shaded cells represent significant differences between participants and non-participants, and between participants receiving or installing smart thermostats through direct install and rebate program delivery channels. Negative percentages reflect answers that indicate a reduction in energy use. For example, the negative percentage for "Using more lighting" indicates that among non-participants, more people (7 percentage points) said they were decreasing their lighting use than increasing it.

Table 4-8. Changes in home impacting energy use

Net Energy Use Increasing Actions[27]	Non-Participants (n=2,407)	All Participants (n=10,151)	Direct Install Participants (n=1,254)	Rebate Participants (n=8,897)
Added electric vehicle charging to the home	4%	7%	1%	8%
Using an additional refrigerator	3%	5%	4%	5%
Household size increased	0%	4%	4%	4%
Increased living area/square footage of your home (finished basement to add media room or bedroom, for example)	1%	2%	-1%	3%
Added a pool	-1%	-1%	-1%	-2%
Added a spa	-2%	-2%	-2%	-1%
Using more lighting	-7%	-2%	-12%	-1%

The analysis reveals that participants reported making changes that likely contributed to their energy use in significantly higher proportions relative to non-participants. We see similar differences with rebate participants reporting changes that increase energy use in significantly higher proportions compared to direct install participants.

[26] Net increase is derived as the difference in the proportion reporting an action that would increase energy use and the proportion that report doing the opposite which would result in decreased energy use for that action.

[27] Negative numbers indicate that the proportion reporting an action that would decrease energy use is greater than the proportion that report an action that would increase energy use.

Despite identification of a comparison group of non-participant customers that are matched to participants based on pre-program consumption, these findings make apparent how self-selection can manifest itself in changes that are unrelated to HVAC use which may have an impact on energy consumption trends. A participant group that reports such changes in greater proportions than non-participants would manifest this trend in a way that could mask actual savings from a measure installation. Given these survey results indicating an upward trend in participant baseload energy consumption relative to the comparison group non-participants, adjustments were applied that would address that trend. See Section 5.2.2 for a discussion of how savings estimates are adjusted for this bias.

4.2.4 Smart thermostat user profile

Over one-quarter (29%) of all non-participants indicated that they had a smart thermostat. Approximately half of **this subset of non-participants** that reported that they had a smart thermostat indicated that they installed their thermostat at a time that could potentially contribute to a downward bias in the estimated savings from the billing analysis. The table below provides a **smart thermostat user profile** which compares program participants and non-participants on their thermostat use and demographics (Table 4-9).

Program participants report enrollment in demand response programs and using the auto-away feature that sets back the thermostat when it does not sense occupancy in the home in higher proportions relative to non-participants with SCTs. While both of these actions contribute to savings achieved by participants, participants also exhibit thermostat use behaviors that contribute to increased energy consumption and reduce savings potential as they are inclined to comfort, remote operation, and pre-heating and pre-cooling the home in higher proportions than non-participants. We see a similar pattern with rebate participants reporting thermostat use behaviors that contribute to increased energy consumption in significantly higher proportions than direct install participants.

Table 4-9. Smart thermostat non-participant and participant user profile

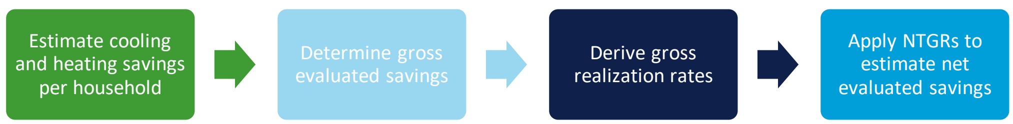
	Non-participants with SCTs (n=685)	All Participants (n=10,151)	Direct Install Participants (n=1,254)	Rebate Participants (n=8,897)
Previous Thermostat Use				
Set it and forget it	17%	31%	30%	31%
Smart Thermostat Use				
Very or somewhat satisfied with smart thermostat	77%	89%	82%	90%
Use the mobile app to access smart thermostat	64%	89%	70%	92%
Remotely adjust home temperature using app	58%	77%	60%	80%
Pre-cool or pre-heat home using app	20%	31%	17%	33%
More comfortable with new smart thermostat vs previous thermostat	49%	62%	51%	63%
Use auto-away feature (to setback thermostat when sensor does not register activity)	28%	48%	24%	51%
Enrolled in demand response program since installing smart thermostat	14%	26%	16%	28%

	Non-participants with SCTs (n=685)	All Participants (n=10,151)	Direct Install Participants (n=1,254)	Rebate Participants (n=8,897)
Demographics				
Dwelling built in 1980 or after	39%	51%	67%	49%
Income above $100,000	43%	44%	19%	48%
Home size above 2,000 square feet	41%	37%	32%	37%

5 IMPACT RESULTS

This section presents estimated cooling and heating savings per household by climate zone for each PA. These estimates are used to generate gross evaluated savings and gross realization rates. Net evaluated savings for each PA are estimated by applying NTGRs to gross evaluated savings (Figure 5-1).

Figure 5-1. Impact evaluation approach

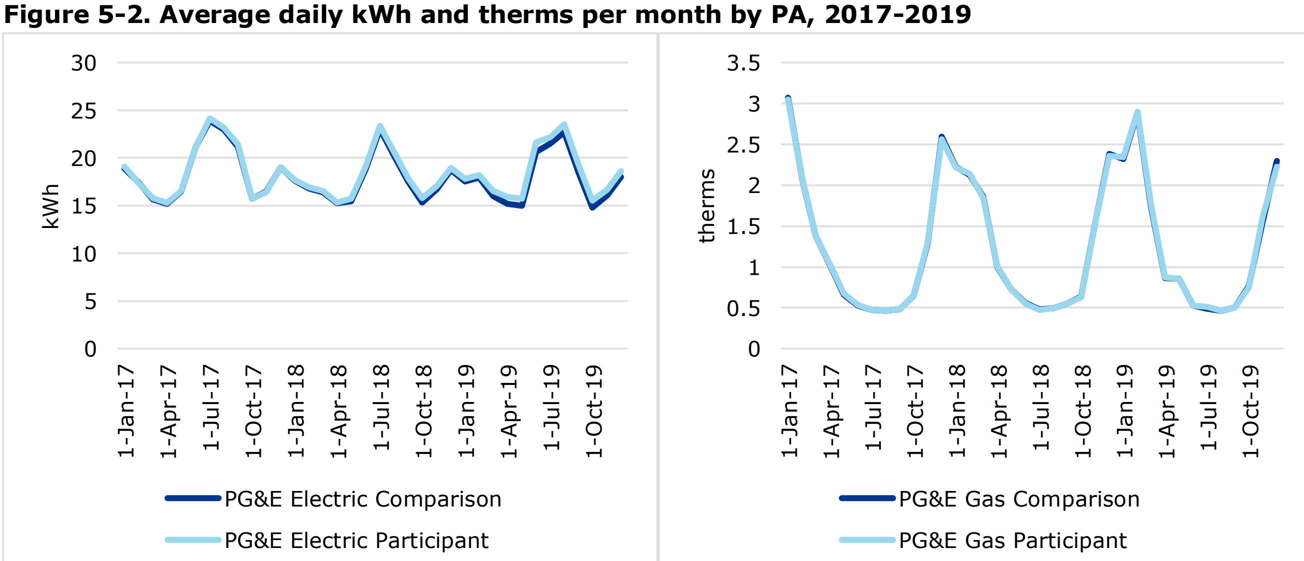


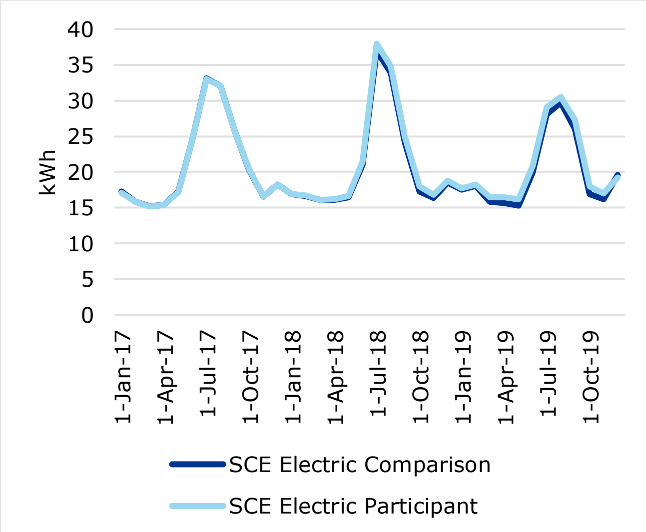
5.1 Energy use trends

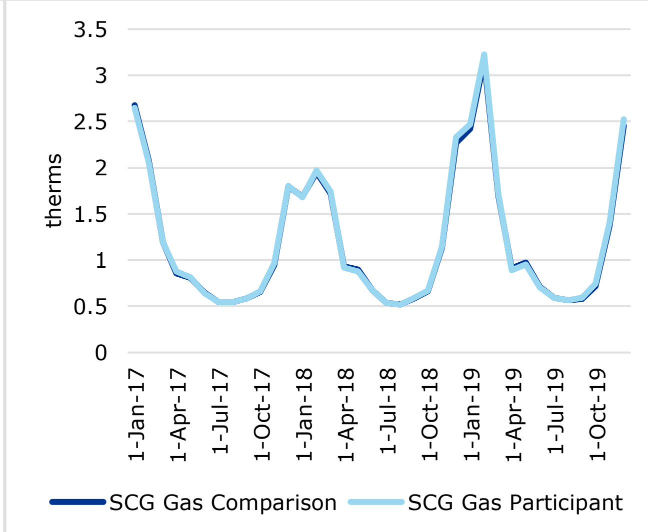
Smart thermostats aim to provide more efficient operation of HVAC systems than conventional thermostats. This evaluation found evidence of heating and cooling savings, particularly in climate zones with higher cooling and heating consumption.

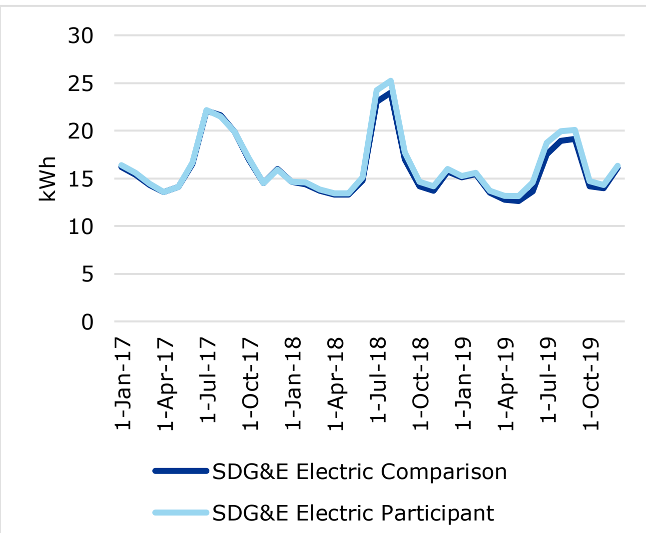
Figure 5-2 provides a preliminary visual examination in of non-weather normalized average energy consumption of those that installed smart thermostats and their matched comparison households over the evaluation period. The figures illustrate the apparent increase in participant electric consumption while showing no evidence of a decrease in gas consumption. The panels in the figure indicate well matched energy use in 2017, prior to smart thermostat installation. In the later months of the electric figures, consistent across PAs, there is a separation between treatment and comparison groups' electricity use indicating greater consumption among participants over time. Gas consumption increases over the later months are not as dramatic but there is no evidence of a decrease.

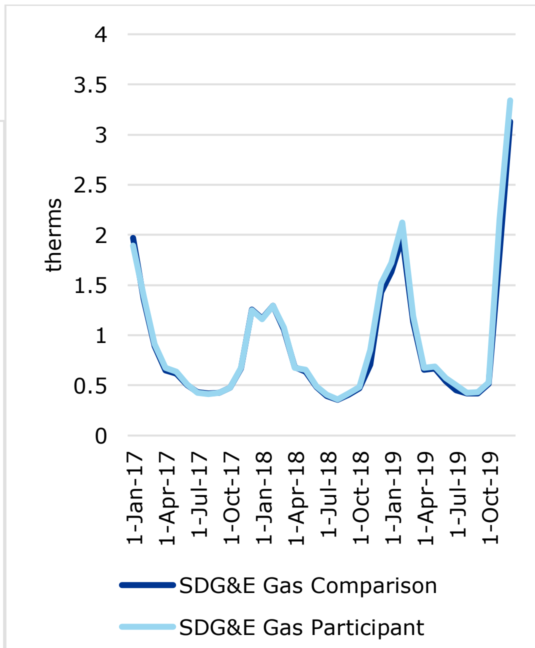
Figure 5-2. Average daily kWh and therms per month by PA, 2017-2019











The two-stage modeling approach results provide savings estimates for baseload, cooling and heating savings separately. While the results do not indicate whole home savings, the heating and cooling components of energy use do show savings. These savings are completely masked in the whole home estimates by a substantial increase in baseload consumption. This is an indication of the presence of a difference in baseload energy consumption trend from pre- to the post-installation periods across the two groups.

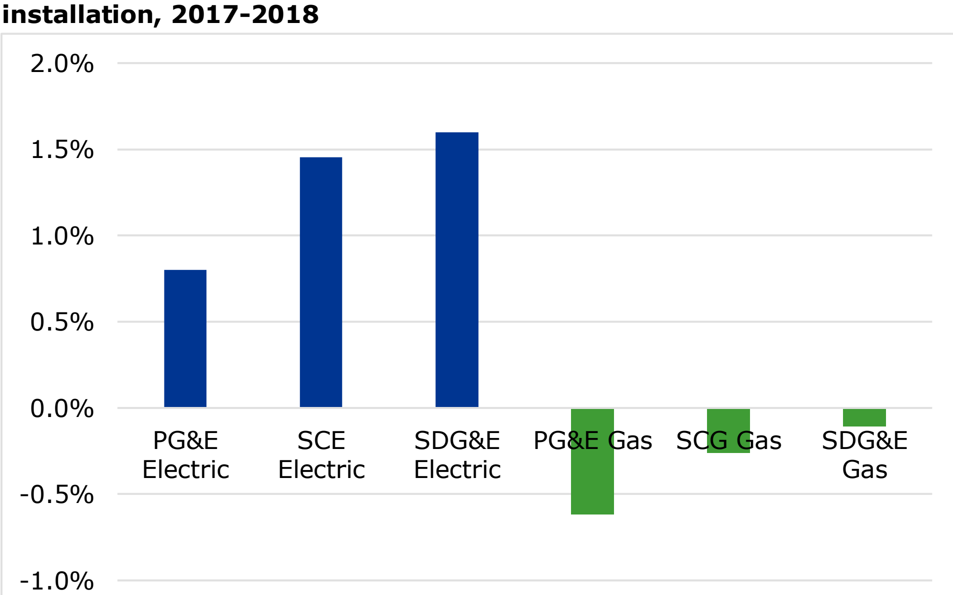
As stated earlier, smart thermostats save energy through a more efficient operation of HVAC systems that are designed to affect cooling and heating energy use. There are limited reasons baseload energy use would be different from pre- to post-installation periods between the two groups with the installation of smart thermostats. One possible way such a difference would arise, as discussed earlier, is continual operation of HVAC fan systems when smart thermostats are installed. In general, however, a pre- to post-period difference in baseload energy use between participant and non-participant groups suggests differences in energy consumption trends between the two groups. Results from surveys conducted by DNV GL indicate that participants were more likely than comparison group households to take actions that increase energy consumption.

To investigate the presence of such trends, DNV GL analyzed changes in energy use between households that installed smart thermostats and their matches prior to smart thermostat installation. Installation of smart thermostats occurred throughout 2018 with the total number of installations increasing over the months. There were, thus, no smart thermostat installations among participants in 2017, a time period during participants were matched with comparison group households. Our analysis involved examining changes in energy consumption of participants and their matched comparison households in the matching period compared to change in consumption for these households from the end of the matching period up to the installation date. This is a difference-in-difference of energy consumption between participants and non-participants prior to the installation of smart thermostats.

For instance, for households that installed smart thermostats in July 2018, the difference in the 2017 energy consumption of these households and their matches is compared to the consumption difference of these pairs in the first 6 months of 2018 (prior to smart thermostat installation). Any two customer groups matched on consumption in one period will diverge over time. However, the upward or downward trend of the energy use of one group suggests that changes other than smart thermostat installation are systematically different for the group.

Figure 5-3 provides the average percent change in electric and gas use pre-installation. On average, there is evidence of increasing electricity use among smart thermostat customers of all PAs, while the there is no indication of such a trend for gas consumption.

Figure 5-3. Participants' average daily electric and gas use trend prior to smart thermostat installation, 2017-2018

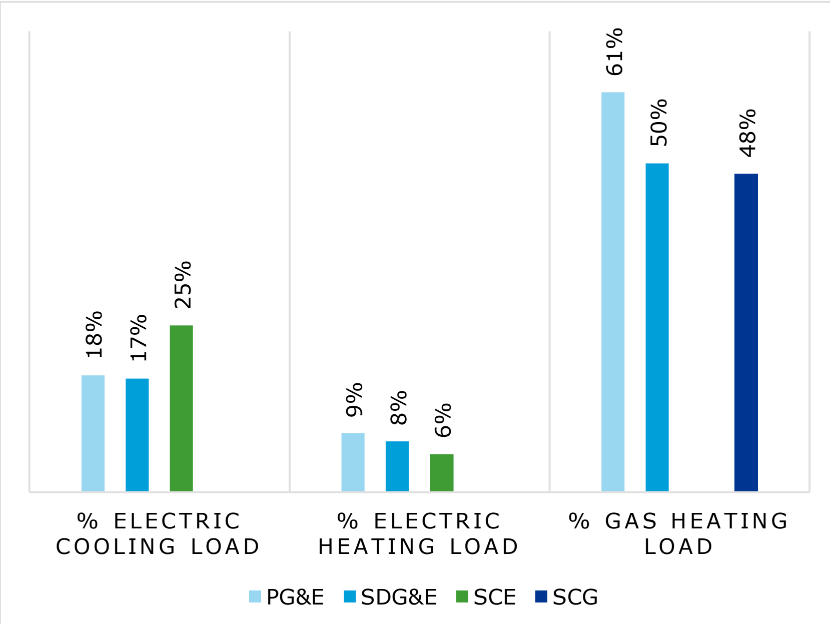


This evidence of upward participant consumption trend and the survey results that provide an explanation for that trend make it necessary to address the potential effects of an upward trend on the savings estimates. The adjustments applied to address this issue are discussed in section 5.2.2.

5.2 Savings per household

On average, electric cooling and heating load make up 17%-25% and 6%-9%, respectively, of total electric load, while gas heating makes up 50%-60% of total gas load (Figure 5-4). Electric cooling and heating load make up a lower portion of total electric load compared to gas heating load.

Figure 5-4. Average estimated percent cooling and heating load by PA, 2018



5.2.1 Regression-based savings estimates

Table 5-1 shows electric savings disaggregated into cooling and heating load, and baseload by PA and climate zone. These estimates are based on difference-in-difference models based on weather normalized cooling and heating load, and baseload. Positive values represent savings while negative terms indicate increases in energy use among treatment customers. Results are presented both in kWh and therms, and as percentages of baseline cooling and heating load and baseload.[28]

Table 5-1. Estimated electric cooling, heating and baseload savings by PA and climate zone

Climate Zone	Estimated Electric Cooling Load Savings (kWh)	Estimated Electric Heating Load Savings (kWh)	Estimated Electric Baseload Savings (kWh)	Percent Electric Cooling Load Savings	Percent Electric Heating Load Savings	Percent Electric Baseload Savings
PG&E						
2	50.3	-16.6	-74.3	9.8%	-2.6%	-1.3%
3	-25.8	-2.4	-80.7	-9.2%	-0.4%	-1.7%
4	25.0	10.3	-149.1	4.7%	1.9%	-2.8%
5	30.8	-58.5	-107.1	13.2%	-16.1%	-2.4%
11	84.2	42.5	-153.0	3.8%	6.4%	-2.4%

[28] Second stage model results on which these estimates are based are provided in Appendix G. Results include these savings estimates as well as the heating, cooling and overall consumption that comprise denominators of the savings percentages. P-values and standard errors, which can be used to assess precision, are provided for all estimates. The standard errors of delta NAC provide indications of the variability of the final adjusted savings. To the extent the confidence bounds on these are wide, they indicate that savings are not big enough to be detectable.

Climate Zone	Estimated Electric Cooling Load Savings (kWh)	Estimated Electric Heating Load Savings (kWh)	Estimated Electric Baseload Savings (kWh)	Percent Electric Cooling Load Savings	Percent Electric Heating Load Savings	Percent Electric Baseload Savings
12	21.7	11.5	-195.3	1.8%	1.9%	-3.3%
13	90.0	23.4	-75.2	3.0%	4.1%	-1.3%
16	32.0	329.8	193.9	6.7%	32.0%	4.6%
SCE						
6	58.2	13.4	-100.8	6.9%	2.5%	-1.8%
8	-18.8	-15.5	-169.3	-1.3%	-3.6%	-3.2%
9	4.3	-4.9	-155.8	0.2%	-1.1%	-2.8%
10	5.6	17.2	-122.0	0.2%	4.6%	-2.1%
13	160.9	20.4	-170.5	5.0%	4.0%	-2.8%
14	96.5	15.2	-167.3	3.6%	3.0%	-3.1%
15	113.1	-1.8	-85.7	2.5%	-0.7%	-1.4%
16	77.2	22.6	-192.3	3.5%	6.8%	-4.4%
SDG&E						
6	12.4	-35.8	-41.9	1.2%	-8.2%	-0.7%
7	2.4	-30.1	-22.7	0.3%	-6.8%	-0.5%
8	73.4	5.9	-174.2	4.9%	1.7%	-2.9%
10	23.6	48.3	-92.9	2.0%	9.6%	-1.9%

There is evidence of electric cooling load savings across most climate zones with higher cooling load. This includes warmer climate zones like 13, 14, and 15. Estimated electric cooling reduction as a percent of cooling load range from -9.2% for the Bay Area to a high of 13% for climate zone 5.[29] In general, estimates of cooling savings are well below 11% of cooling consumption that is the basis for savings claims in the current workpaper. Electric heating savings were not included in the current workpaper because no valid estimates of such savings were found. The current evaluation does indicate the presence of some electric heating savings.

Most climate zones show strong increase in electric baseload, which is most likely tied to increasing trend in electricity use among participant households. While the quasi-experimental design strives to find balance between participants and households selected as comparison group members, it cannot fully account for all factors that influence trends in energy consumption, some of which are unobservable. Such factors could drive the noted increase in baseload. Our analysis shows a trend of increasing baseload electricity consumption among the population adopting smart thermostats, which is a contributing factor to the lack of total savings. This increase could either be related directly to HVAC system controls (increased fan usage[30]) and/or to exogenous trends in energy consumption among customers who choose to adopt smart thermostats.

Table 5-2 presents results from difference-in-difference models that estimate gas heating and baseload savings. Gas heating savings are positive for most of PG&E’s and SDG&E’s climate zones and represent

[29] Some of the variations in results across PAs within the same climate zone reflect small numbers of participants in one or more of these groupings. While there is variability in usage, savings, usage and savings components across customers, and therefore across groups of customers within a climate zone, the overall results by PA are based on large numbers of customers where the variability is mitigated by aggregation; PA level unadjusted estimates would have reasonable precision.

[30] Major smart thermostat models offer the option of setting a daily timer on the system ventilation fan while setting up other system default settings. As a new functionality not available on most programmable thermostats, use of this capability would likely increase consumption generally, and an increase due to a regularly scheduled fan would show up in the baseload portion of the estimate.

2.2%-3.6% of gas heating consumption. Gas heating savings are more limited in SCG's service territory.[31] Moreover, there is indication of gas baseload savings for PG&E. Like electric heating savings, gas heating savings were not included in the current workpaper because of lack of valid estimates of savings. This evaluation finds modest gas heating savings in some climate zone.[32]

Table 5-2. Estimated gas heating and baseload savings by PA and climate zone

Climate Zone	Initial Estimated Gas Heating Load Savings (therms)	Initial Estimated Gas Baseload Savings (therms)	Percent Gas Heating Load Savings	Percent Gas Baseload Savings
PG&E				
2	11.7	0.4	3.6%	0.2%
3	10.1	0.2	3.6%	0.1%
4	7.6	2.3	2.8%	1.3%
11	-1.0	3.5	-0.4%	1.8%
12	6.5	-5.2	2.2%	-2.9%
13	6.6	3.4	2.5%	2.1%
SCG				
4	-26.7	3.2	-11.7%	1.4%
5	-5.2	-3.2	-2.6%	-1.4%
6	3.0	-3.7	1.3%	-1.5%
8	0.2	2.5	0.1%	1.2%
9	-1.5	-1.9	-0.7%	-0.8%
10	-1.5	-1.9	-0.8%	-0.9%
13	9.9	1.4	4.2%	0.7%
14	20.1	-6.8	6.4%	-3.5%
15	-1.2	15.2	-0.8%	8.9%
16	2.6	-2.3	1.1%	-1.1%
SDG&E				
7	5.1	0.9	3.1%	0.5%
10	4.0	-1.2	2.3%	-0.7%

As noted above, baseload increases could be tied to factors unrelated to smart thermostat installation such as changes in dwelling size, household occupancy, and other unobserved characteristics that drive households to choose to participate in a program offering smart thermostats. There is a higher prevalence of households with such characteristics among the participant group as indicated by survey results (Section 5.2). This upward trend in overall consumption would mask potential savings from smart thermostats.

5.2.2 Adjustments to regression-based savings estimates

DNV GL applied 3 adjustment factors to the estimated to the cooling and heating savings presented above.

In an attempt to mitigate the effects of possible *self-selection bias*, an adjustment is applied to cooling and heating savings estimates that removes the estimated differential trend in baseload. This adjustment involves adding the percent change in baseload to the percent change in electric cooling and heating estimates. This adjustment attributes all of the change in baseload consumption to customer self-selection

[31] Similar to electricity, some of the variations in results across PAs within the same climate zone reflect small numbers of participants in one or more of these groupings. Overall results by PA are based on large numbers of customers where the variability is mitigated by aggregation and PA level unadjusted estimates would have reasonable precision.

[32] Second stage model results on which these estimates are based are provided in Appendix G. Results include these savings estimates as well as the heating, cooling and overall consumption that comprise denominators of the savings percentages. P-values and standard errors, which can be used to assess precision, are provided for all estimates. The standard errors of delta NAC provide indications of the variability of the final adjusted savings. To the extent the confidence bounds on these are wide, they indicate that savings are not big enough to be detectable.

and assumes that electric cooling and heating consumption experience the same overall percentage trend, unrelated to the SCT, seen in the baseline.

Since not all customers demonstrate heating and/or cooling consumption in their site-level models, DNV GL also put cooling and heating savings estimates on a per customer basis. In general, 80% of customers have estimated cooling and 80% heating load. This process does not affect overall cooling and heating savings estimates but does adjust downward the per-customer savings estimates.

Finally, savings estimates are adjusted upward to account for the prevalence of smart thermostats among the comparison group. Results from surveys of comparison group households reveal that 5% to 5.9% installed smart thermostats in 2018 and 5.4% to 6.7% installed smart thermostats in 2019. These are periods during which participants installed smart thermostats and during which the effect of smart thermostats on energy consumption are measured for this group.[33] If comparison group smart thermostat installations are assumed to have the same savings effect in the matched comparison households as program thermostats, then there presence will have the effect of diminishing the magnitude of potential savings estimates for participants.

Table 5-3 provides the installation rates of smart thermostats among the comparison group for each PA. It also provides the multiplicative adjustment factors used to account for these rates. For example, a prevalence of 12.6% smart thermostats among comparison group households requires that savings estimates be divided by (1-0.126 = 0.874) or multiplied by its reciprocal (1.14). This is a modest upward adjustment that assumes that all comparison group installations perfectly correlate with installation of program participants.

Table 5-3. Adjustment factors for the presence of smart thermostats among the comparison group by PA

	Percent Comparison Group Households that Installed Smart Thermostats			Comparison Group Adjustment Factor
	2018	2019	2018-2019 Total	2018-2019 Effects
PG&E	5.9%	6.7%	12.6%	1.14
SCE	4.8%	5.3%	10.1%	1.11
SCG	5.7%	7.5%	13.2%	1.15
SDG&E	5.0%	5.4%	10.4%	1.12

The adjustment for cooling and heating savings are summarized by the following equations:

$$\begin{aligned}&adjusted\ electric\ cooling\ savings\\&\quad = \big((percent\ electric\ cooling\ load\ savings + -1 * percent\ baseload\ savings)\\&\quad * estimated\ electric\ cooling\ load\ ) * \ \ estimated\ proportion\ with\ electric\ cooling\ load\big)\\&\quad * \ comparison\ group\ adjustment\ factor\end{aligned}$$

[33] A thermostat installed by a non-participant household at any point during the pre- or post-installation window will have the potential to downwardly bias the savings estimates. The closer in time the non-participating thermostat is installed to the installation date of its matched household, the greater the potential for downward bias on the savings estimate, up to a 100% effect if the thermostats were installed at same time. Though the moving window of this analysis covers three years, only two years of consumption are included per customer. With the rising install rate of smart thermostats in the market, the installation rate for 2018 and 2019 represents a reasonable estimate of comparison group installation rates for the evaluation. The rate is applied assuming that those thermostats were installed at the same time as the installation at their match household.

$$\begin{aligned} &adjusted\ electric\ heating\ savings \\ &\quad = ((percent\ electric\ heating\ load\ savings\ +\ -1 * percent\ baseload\ savings) \\ &\quad * estimated\ electric\ heating\ load\ ) *\ estimated\ proportion\ with\ electric\ heating\ load) \\ &\quad *\ comparison\ group\ adjustment\ factor \end{aligned}$$

$$\begin{aligned} &adjusted\ gas\ heating\ savings \\ &\quad = ((percent\ gas\ heating\ load\ savings\ +\ -1 * percent\ baseload\ savings) \\ &\quad * estimated\ gas\ heating\ load\ ) *\ estimated\ proportion\ with\ gas\ heating\ load) \\ &\quad *\ comparison\ group\ adjustment\ factor \end{aligned}$$

Table 5-4 presents all three factors used to adjust estimated electric cooling load. Percent adjusted cooling load savings, which are the sum of percent electric cooling load savings and percent increase in baseload savings are multiplied by estimated electric cooling load to get savings estimates that account for possible self-selection bias. Additionally, this value is multiplied by the estimated proportion of customers with cooling load and by the factor that adjusts for installation of smart thermostats among the comparison group. The resulting final electric cooling savings are presented in the last column.

Table 5-4. Electric cooling savings adjustments by PA and climate zone

Climate Zone	Initial Estimated Electric Cooling Load [A]	Percent Adjusted Electric Cooling Savings [B]	Estimated Proportion with Electric Cooling Load [C]	Comparison Group Adjustment Factor [D]	Final Estimated Electric Cooling Savings [E = A*B*C*D]
PG&E					
2	513	11.1%	0.78	1.14	51.0
3	279	-7.5%	0.85	1.14	-20.4
4	530	7.5%	0.70	1.14	31.6
5	232	15.7%	0.89	1.14	37.0
11	2,208	6.3%	0.87	1.14	137.6
12	1,183	5.2%	0.75	1.14	52.0
13	3,012	4.3%	0.93	1.14	136.3
16	480	2.1%	0.85	1.14	9.7
SCE					
6	841	8.7%	0.66	1.11	53.7
8	1,443	1.9%	0.71	1.11	21.7
9	1,898	3.0%	0.76	1.11	48.3
10	2,311	2.3%	0.79	1.11	47.5
13	3,245	7.7%	0.87	1.11	243.6
14	2,702	6.7%	0.88	1.11	177.2
15	4,478	3.9%	0.84	1.11	164.1
16	2,178	7.9%	0.68	1.11	131.0
SDG&E					
6	1,057	1.9%	0.59	1.12	13.3
7	824	0.8%	0.59	1.12	4.3
8	1,508	7.8%	0.64	1.12	83.9
10	1,189	3.9%	0.56	1.12	28.6

Factors used to adjust electric heating load are presented in Table 5-5. The adjustments are analogs to those made for electric cooling load. Similarly, the table also provides the final electric heating load savings in the last column.

Table 5-5. Electric heating load savings adjustments by PA and climate zone

Climate Zone	Initial Estimated Electric Heating Load [A]	Percent Adjusted Electric Heating Savings [B]	Estimated Proportion with Electric Heating Load [C]	Comparison Group Adjustment Factor [D]	Final Estimated Electric Heating Savings [E = A*B*C*D]
PG&E					
2	645	-1.3%	0.81	1.14	-7.8
3	583	1.3%	0.67	1.14	5.7
4	538	4.7%	0.78	1.14	22.6
5	364	-13.7%	0.76	1.14	-43.4
11	662	8.9%	0.85	1.14	56.9
12	620	5.2%	0.80	1.14	29.4
13	569	5.4%	0.86	1.14	30.3
16	1,030	27.4%	0.90	1.14	290.7
SCE					
6	526	4.3%	0.83	1.11	20.9
8	435	-0.4%	0.86	1.11	-1.5
9	443	1.7%	0.87	1.11	7.3
10	377	6.6%	0.91	1.11	25.4
13	504	6.8%	0.92	1.11	35.0
14	507	6.1%	0.83	1.11	28.5
15	283	0.8%	0.95	1.11	2.3
16	330	11.2%	0.82	1.11	33.9
SDG&E					
6	438	-7.4%	0.77	1.12	-28.1
7	439	-6.3%	0.77	1.12	-23.9
8	349	4.6%	0.87	1.12	15.7
10	504	11.5%	0.81	1.12	52.5

Estimated and adjusted electric cooling and heating savings are presented in Table 5-6. The last column in the table provides values of electric savings per household that are used to evaluate claimed or reported savings for each PA and climate zone. In general, electric savings per household are highest for climate zones with substantial cooling loads (climate zones 11, 13, 14, and 15) and heating loads (climate zones 11 and 16). These climate zones are within the service territories served by PG&E and SCE. Among SDG&E's climate zones, the less temperate inland climate zones 8 and 10 have higher electric savings. For comparison purpose, expected electric savings per unit of installed smart thermostat for each PA and climate zone are provided in Appendix I.

Table 5-6. Initial and final electric savings estimates per household by PA and climate zone

Climate Zone	Electric Cooling Savings Estimates		Electric Heating Savings Estimates		Electric Cooling and Heating Savings Estimates	
	Initial	Final	Initial	Final	Initial	Final
PG&E						
2	50.3	51.0	-16.6	-7.8	33.8	43.1
3	-25.8	-20.4	-2.4	5.7	-28.2	-14.7
4	25.0	31.6	10.3	22.6	35.2	54.2
5	30.8	37.0	-58.5	-43.4	-27.7	-6.3
11	84.2	137.6	42.5	56.9	126.7	194.5
12	21.7	52.0	11.5	29.4	33.2	81.4
13	90.0	136.3	23.4	30.3	113.4	166.5

Climate Zone	Electric Cooling Savings Estimates		Electric Heating Savings Estimates		Electric Cooling and Heating Savings Estimates	
	Initial	Final	Initial	Final	Initial	Final
16	32.0	9.7	329.8	290.7	361.9	300.4
SCE						
6	58.2	53.7	13.4	20.9	71.6	74.6
8	-18.8	21.7	-15.5	-1.5	-34.4	20.2
9	4.3	48.3	-4.9	7.3	-0.5	55.6
10	5.6	47.5	17.2	25.4	22.8	72.8
13	160.9	243.6	20.4	35.0	181.3	278.6
14	96.5	177.2	15.2	28.5	111.7	205.6
15	113.1	164.1	-1.8	2.3	111.2	166.4
16	77.2	131.0	22.6	33.9	99.8	164.9
SDG&E						
6	12.4	13.3	-35.8	-28.1	-23.4	-14.7
7	2.4	4.3	-30.1	-23.9	-27.6	-19.5
8	73.4	83.9	5.9	15.7	79.3	99.5
10	23.6	28.6	48.3	52.5	71.9	81.1

Estimated gas heating savings per households are adjusted similarly. Unlike in the case for electricity, participants households in some climate zones have gas baseload savings that also indicate a presence of a difference in trend between treatment and comparison group households. Such savings are subtracted from estimated gas heating savings in the same manner as gas baseload increases are added to estimated gas heating savings. All other adjustments are otherwise the same as in the electric case. The details are presented in Table 5-7.

Table 5-7. Gas heating load savings adjustments by PA and climate zone

Climate Zone	Initial Estimated Gas Heating Load [A]	Percent Adjusted Gas Heating Savings [B]	Estimated Proportion with Gas Heating Load [C]	Comparison Group Adjustment Factor [D]	Final Estimated Gas Heating Load Savings [E = A*B*C*D]
PG&E					
2	319	3.5%	0.90	1.14	11.3
3	277	3.6%	0.77	1.14	8.6
4	266	1.6%	0.88	1.14	4.3
11	277	-2.2%	0.89	1.14	-6.2
12	297	5.1%	0.88	1.14	15.1
13	265	0.4%	0.88	1.14	1.0
SCG					
4	228	-13.1%	0.98	1.15	-33.9
5	202	-1.2%	0.80	1.15	-2.2
6	225	2.9%	0.69	1.15	5.1
8	172	-1.1%	0.71	1.15	-1.5
9	224	0.1%	0.67	1.15	0.2
10	184	0.0%	0.77	1.15	0.1
13	239	3.4%	0.95	1.15	9.0
14	314	10.0%	0.91	1.15	32.9
15	140	-9.7%	0.68	1.15	-10.7
16	247	2.2%	0.87	1.15	5.4
SDG&E					

Climate Zone	Initial Estimated Gas Heating Load [A]	Percent Adjusted Gas Heating Savings [B]	Estimated Proportion with Gas Heating Load [C]	Comparison Group Adjustment Factor [D]	Final Estimated Gas Heating Load Savings [E = A*B*C*D]
7	162	2.6%	0.50	1.1	2.4
10	175	3.0%	0.53	1.1	3.1

Estimated and adjusted gas heating savings are provided in Table 5-8. Adjusted gas heating savings are used to evaluate claimed savings by each PA and climate zone. Adjusted gas savings per household from SCG are used to evaluate gas savings claims made by SCE. Climate zones 2 and 12 in PG&E's service territory and 14 in SCG's service territory have the highest gas heating loads, which are estimated to be about 300 therms per year, and the highest gas heating savings per household. For comparison purpose, expected gas savings per unit of installed smart thermostat for each PA and climate zone are provided in Appendix I.

Table 5-8. Initial and final gas savings estimates by PA and climate zone

Climate Zone	Initial Estimated Gas Heating Savings	Final Estimated Gas Heating Savings
PG&E		
2	11.7	11.3
3	10.1	8.6
4	7.6	4.3
11	-1.0	-6.2
12	6.5	15.1
13	6.6	1.0
SCG		
4	-26.7	-33.9
5	-5.2	-2.2
6	3.0	5.1
8	0.2	-1.5
9	-1.5	0.2
10	-1.5	0.1
13	9.9	9.0
14	20.1	32.9
15	-1.2	-10.7
16	2.6	5.4
SDG&E		
7	5.1	2.4
10	4.0	3.1

PA-level adjusted electric and gas savings are provided in Table 5-9. They are weighted sum values of climate zone level adjusted savings. Electric cooling savings estimates from SCE's climate zones are used to evaluate electric savings claims by SCG since there is considerable overlap in customers these PAs serve and in the delivery of smart thermostats in some of the programs they run. Because SCG claims gas heating savings, only the electric cooling savings estimates are applied to evaluate its electric savings. Similarly, SCG's gas heating savings are used to evaluate the gas savings claims by SCE and are used to generate the gas savings per household estimated provided in the table.

Table 5-9. Final estimated electric and gas savings per household by PA

PA	Electric Savings (kWh)	Gas Savings (therms)
PG&E	89.8	7.7
SCE	79.7	0.9
SCG	60.7	0.9
SDG&E	35.7	2.9
Statewide	**72.2**	**2.1**

5.3 Total program savings

Savings per household are used to generate total evaluated savings. For each PA, estimates of climate zone level savings per household times the number of participants in the climate zone are used to compute savings for the climate zone. Total evaluated savings at the PA level is the sum of the climate zone estimated savings. Table 5-10 provides total PA-claimed gross electric (savings the PAs expected the measure to deliver), total gross evaluated savings generated at the climate zone level and aggregated to the PA level and the ratio between the two (gross realization rates) by PA for program year 2018. The gross realization rates indicate that measure delivered 14% to 42% of total savings that the PAs expected. Statewide, smart thermostats were expected to provide electric savings of 41.4 GWh and produced 13.7 gross GWh of savings. These savings are further transformed to reflect what portion of the acquisition of the device can be attributed to the programs that delivered them. The final net evaluated savings, which incorporate NTG adjustments, are 11.1 GWh statewide.

Table 5-10. Total smart thermostat electric savings, 2018

Program Administrator	Program participants (Electric)	Total Gross Claimed Savings (kWh)	Total Gross Evaluated Savings (kWh)	Gross Realization Rate	NTG Ratio	Total Net Evaluated Savings (kWh)
PG&E	35,522	7,582,785	3,191,260	42%	70%	2,242,484
SCE	76,922	17,440,307	6,127,389	35%	84%	5,158,682
SCG	65,557	13,281,679	3,976,667	30%	85%	3,398,535
SDG&E	12,014	3,073,459	428,476	14%	77%	329,355
Statewide	**190,015**	**41,378,231**	**13,723,792**	**33%**	**81%**	**11,129,056**

Note: SCE electric savings per household are used to estimate electric savings for SCG as there is a lot of overlap both in customers served and in the way some of the programs delivered smart thermostats

Table 5-11 provides total gross and evaluated gas savings and the associated realization rates by PA. The realization rates for gas savings were lower than for electric and ranged from 7% to 37%. In 2018, the programs that offered smart thermostats were expected to save 3 million therms statewide and delivered evaluated savings of about 459,000 therms. The final evaluated net gas savings statewide were about 348,000 therms.

Table 5-11. Total smart thermostat gas savings, 2018

Program Administrator	Program participants (Gas)	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate	NTG Ratio	Total Net Evaluated Savings (therms)
PG&E	35,543	743,211	273,934	37%	70%	192,492
SCE	76,922	833,531	65,865	8%	84%	55,452
SCG	100,496	1,267,756	92,683	7%	85%	79,209

Program Administrator	Program participants (Gas)	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate	NTG Ratio	Total Net Evaluated Savings (therms)
SDG&E	9,496	160,282	27,412	17%	77%	21,071
Statewide	**222,457**	**3,004,781**	**459,894**	**15%**	**76%**	**348,223**

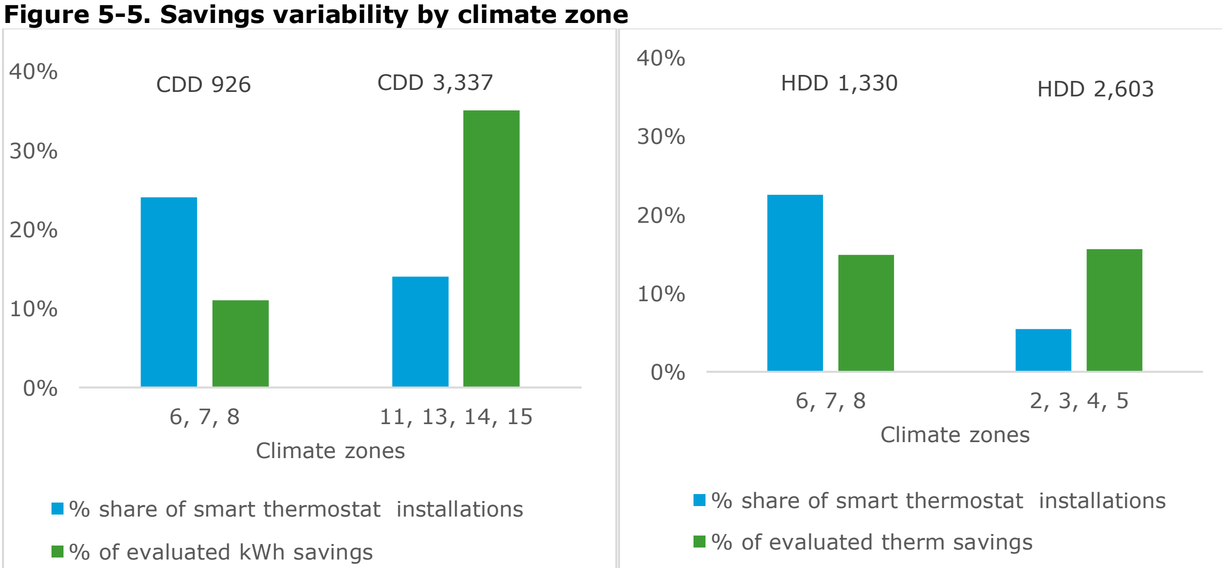
Note: SCG gas savings per household are used to estimate gas savings for SCE as there is a lot of overlap both in customers served and in the way some of the programs delivered smart thermostats

5.4 Savings variability by climate zone

As section 5.2 shows (also Appendix I), we see differences in cooling and heating savings by climate zone. We present an example that underscores savings variability by climate zone below (Figure 5-5). This example contrasts savings from installations in areas with high cooling and heating needs versus those with relatively lower heating and cooling needs. Smart thermostat installations in climate zones 11, 13, 14 and 15 represent 14% of all installations (3,337 cooling degree days) and deliver 35% of evaluated electric savings (4.8 MWh). Although these climate zones exhibited relatively better performance, this 4.8 MWh still falls short and represents 35% of PA claimed savings for these climate zones (13.6 MWh).

Conversely, climate zones 6,7 and 8 (926 cooling degree days) representing 24% of program installations deliver relatively lower kWh savings of 11% (1.5 MWh). This 1.5 MWh represents 28% of PA claimed savings for these climate zones (5.4 MWh). We see similar patterns with installations in climate zones with high heating load delivering a higher proportion of evaluated savings than installations in milder climates.

Figure 5-5. Savings variability by climate zone



These results suggest that the program can achieve better results with improved targeting to customers in areas with high cooling and heating loads.

6 LOAD SAVINGS SHAPES

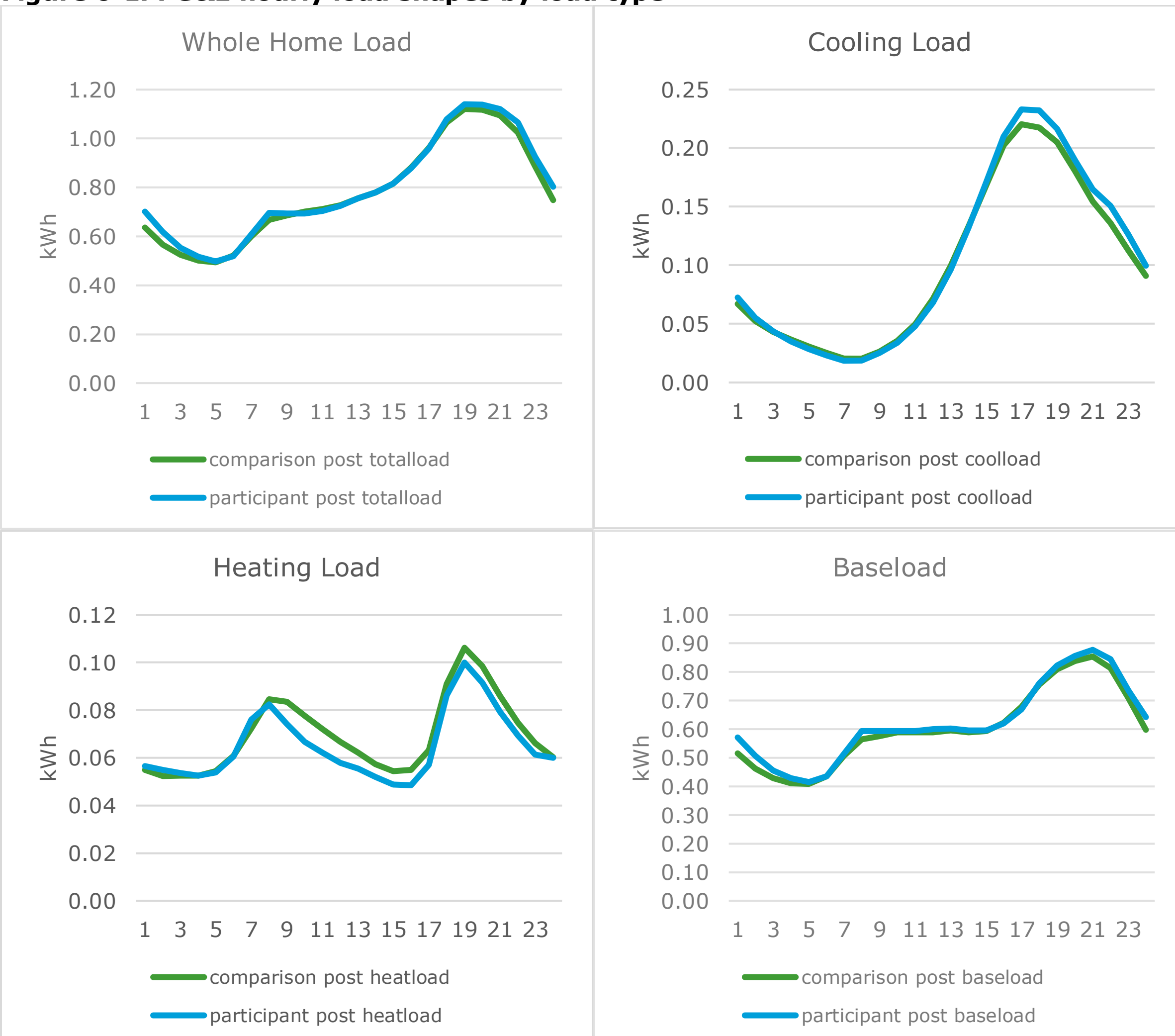
6.1 Hourly load shapes

Weather normalized average hourly load shapes for the three electric PAs are presented in this section. Figure 6-1 presents weather normalized average hourly whole home, cooling, heating, and baseload shapes for PG&E. The panels present the load shapes for the post period in order to illustrate clearly the differences between the participant and comparison groups' load shapes.

The estimated hourly load shapes indicate that baseload makes up about 70% to 80% of whole home hourly load. Cooling load makes up 3% (for early morning hours) to 24% (for the afternoon hours of 3:00 p.m.–6:00 p.m.) of whole home load. Heating load, which makes up 6% to 13% of whole home hourly load, is highest in the early morning (6:00 a.m.–9:00 a.m.) and early evening hours (6:00 p.m.–8:00 p.m.).

Participants' whole home, baseload, and cooling load are higher in the post period than the comparison groups' hourly loads in these categories, especially starting at 4:00 p.m. It is probable that this divergence, which exists to a lesser degree in the pre-installation period, captures the divergence in energy use trends due to self-selection discussed in the two prior sections. Heating load, on the other hand, is lower for the participants in the post-smart thermostat installation period.

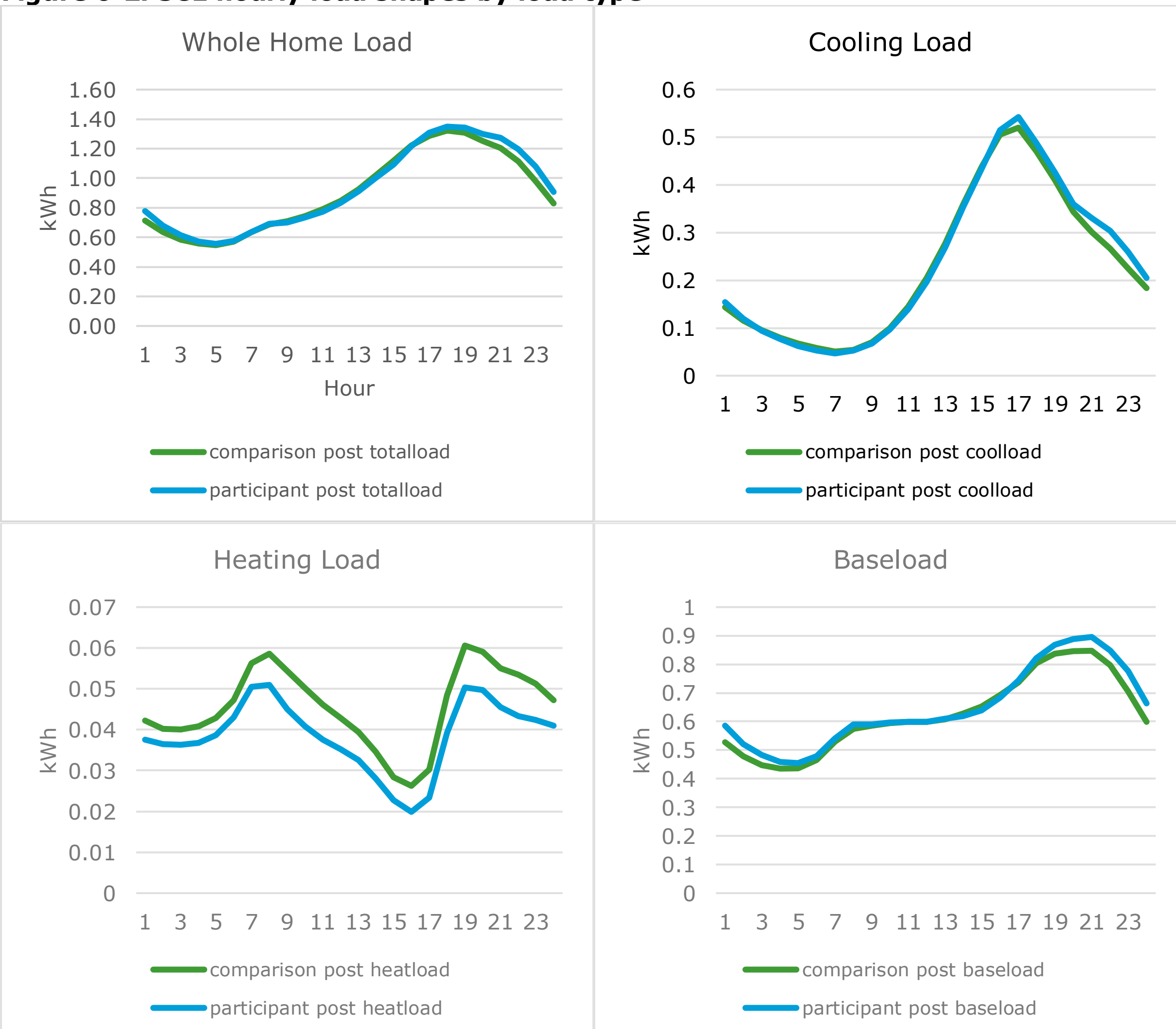
Figure 6-1. PG&E hourly load shapes by load type



Hours are on the x-axis.

Figure 6-2 presents SCE's hourly load shapes. SCE customers' hourly energy consumption is higher than PG&E's, but the patterns are the same. Except for heating load, participants' hourly loads are higher than the comparison group's in the post period, particularly from about 4 p.m. onwards. In SCE's case too, it is likely that this divergence, which exists to a smaller degree pre-installation of smart thermostats, is in part due to self-selection. The composition of cooling and heating load are also similar, but estimated cooling load is higher ranging from about 8% to 40% of whole-home hourly load for SCE. Estimated heating load makes up 2% to 10% of whole-home hourly load.

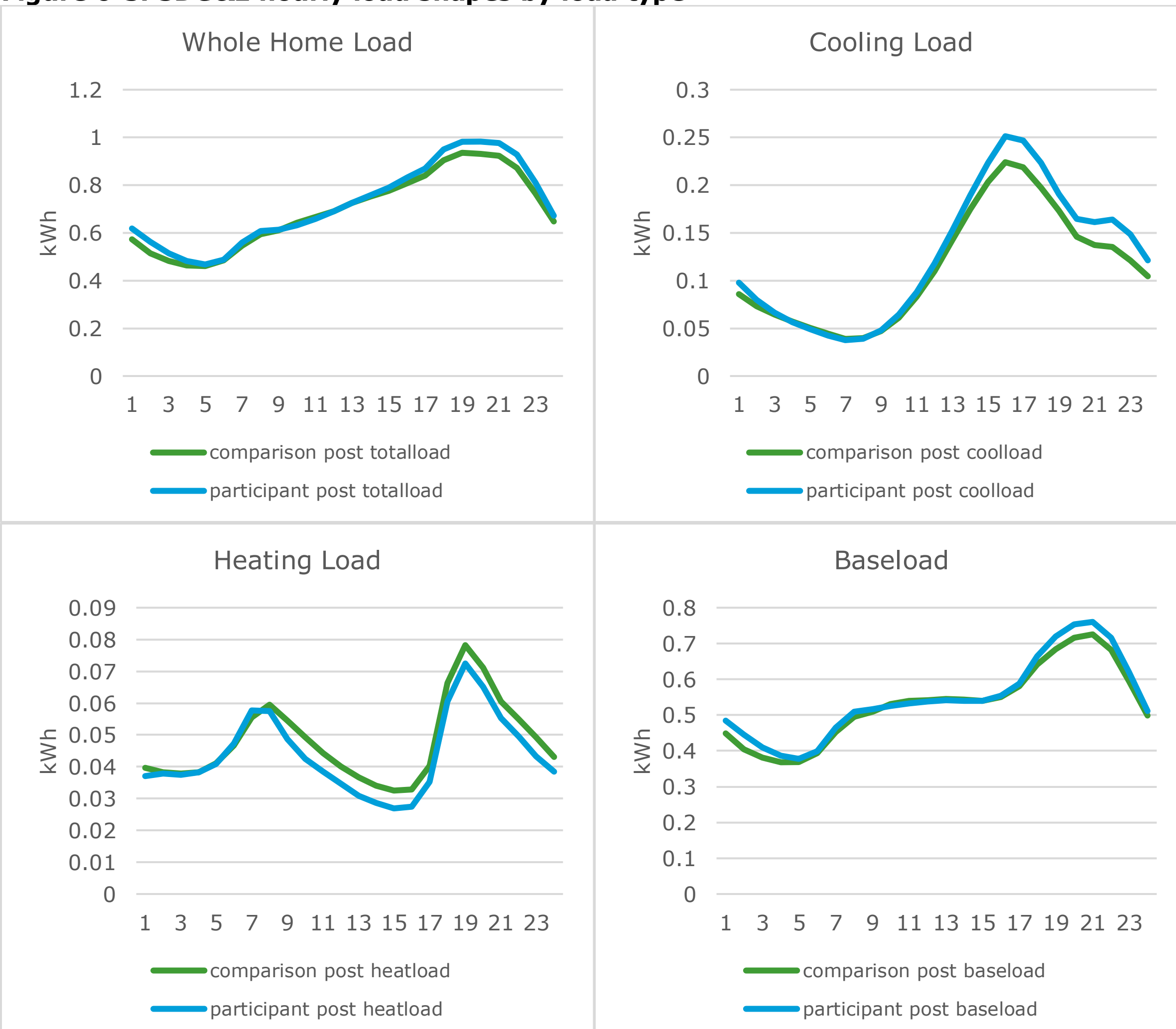
Figure 6-2. SCE hourly load shapes by load type



Hours are on the x-axis.

Figure 6-3 presents the average hourly load shapes for SDG&E. The patterns in this are similar to those presented above. The increase in participants' weather normalized cooling load for the post period is greater for SDG&E than for the other two PAs. SDG&E's estimated cooling load is about 7% to 28% of whole-home hourly load while estimated heating load is about 4% to 10%.

Figure 6-3. SDG&E hourly load shapes by load type



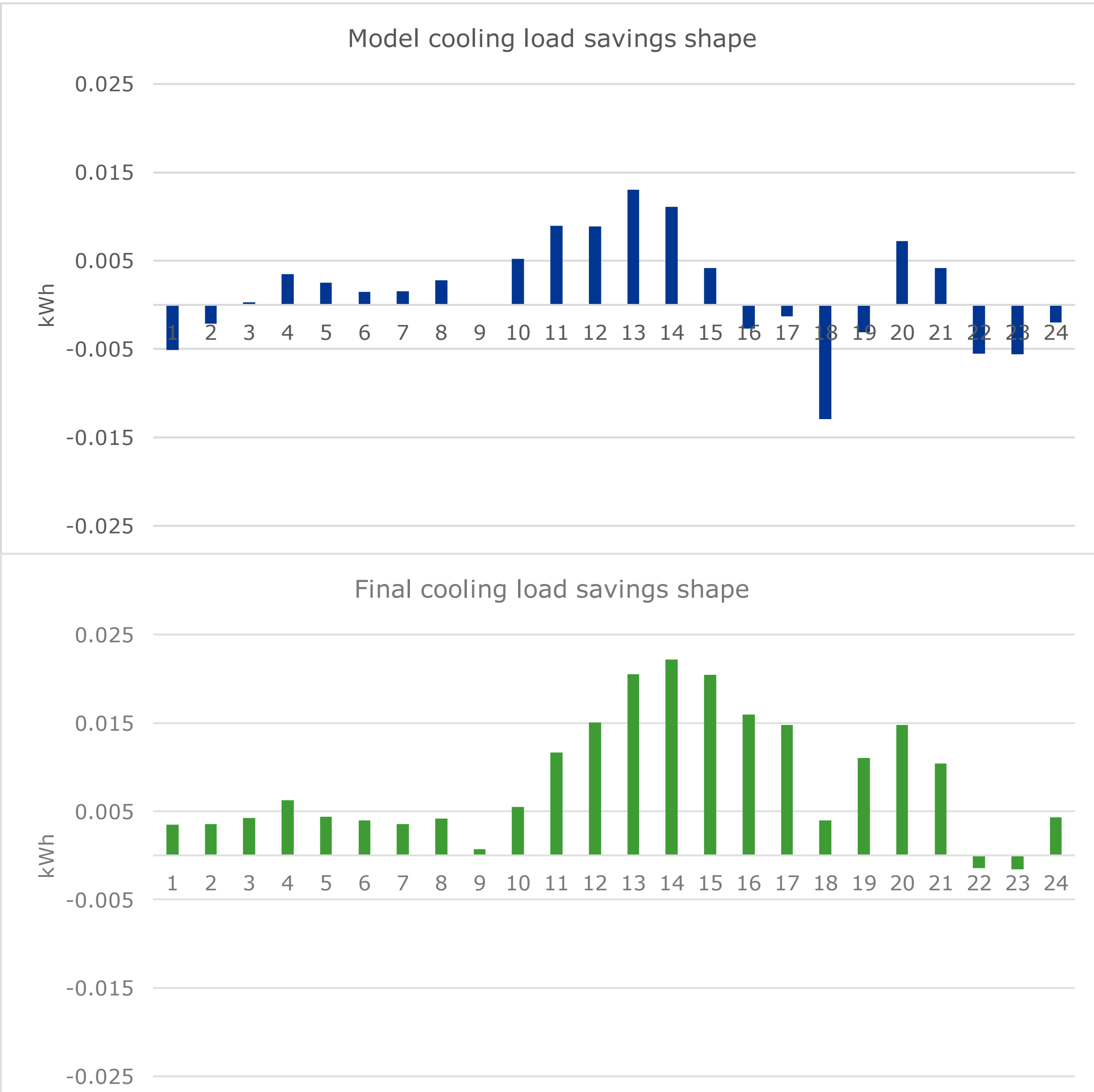
Hours are on the x-axis.

6.2 Hourly load savings shapes

The approach used to estimate hourly load savings shapes is consistent with annual savings methods used in this report. This is an advantage because it should produce results that are in line with annual savings. It also means that the load savings shapes share the challenge of the apparent upward trend in participant consumption compared to the comparison group. A similar approach is used to adjust for this increasing trend when estimating hourly load savings shapes. For both PG&E and SCE, the adjustments make the load savings shapes substantially more consistent with expectations for a cooling-related measure. This serves as a further piece of evidence that there is an upward baseload trend that is obscuring the cooling savings effects of this measure.

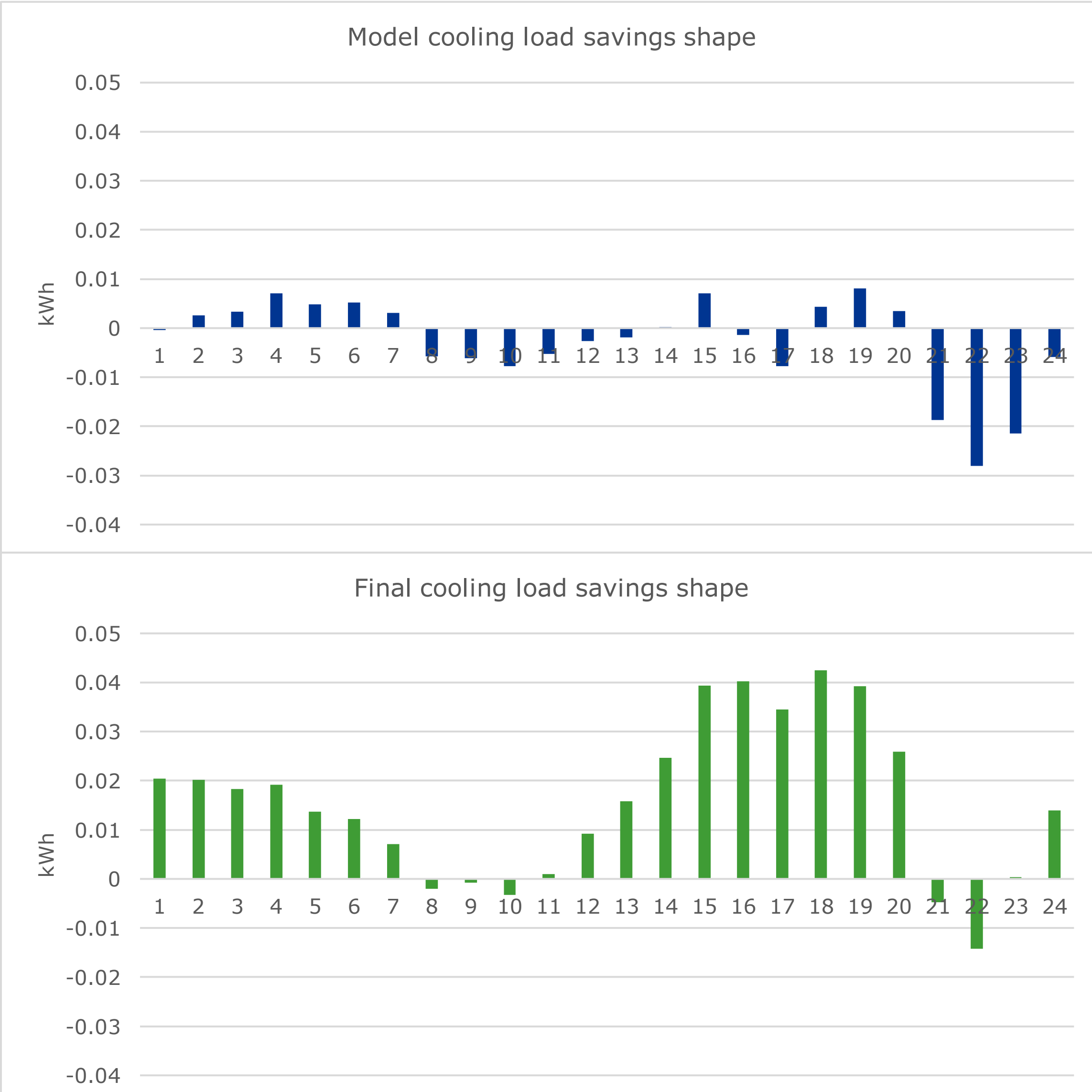
The plots below (Figure 6-4, Figure 6-5, and Figure 6-6) provide the preliminary difference-in-difference cooling load savings shapes in the top panel. The lower panels provide the estimates of summer cooling load savings shapes that reflect the adjustments to address upward trend in energy consumption among participants. PG&E's hourly load savings shape based on the initial model estimates reflects savings around midday, well before the later cooling peak load period. The adjusted final estimates extend the savings later in the day, though savings still appear to diverge from the cooling peak load hours. This would be consistent with fewer savings opportunities for smart thermostats when people are at home and cool more for comfort. Overall, savings are no more than 5% of summer cooling baseline load.

Figure 6-4. PG&E estimated hourly load savings shapes



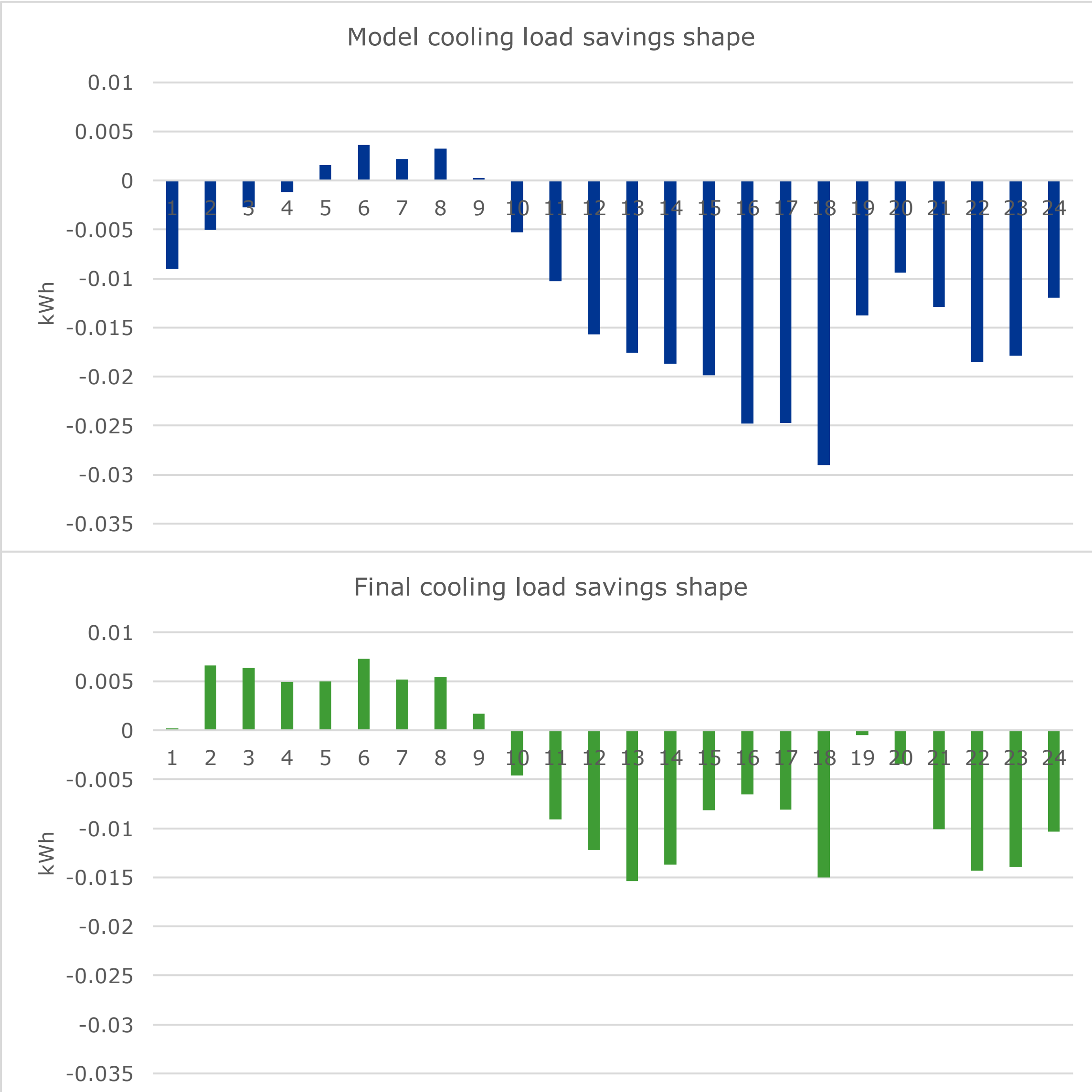
SCE's initial estimated cooling load savings shape shows savings without any relation to the cooling load peak. Again, the final adjusted cooling load savings shape is more consistent with the cooling peak load shape, but it still diverges from it in the late afternoon and early evening hours. In this case too, there appears to be limited savings when people are home and cooling for comfort. SCE's estimated load savings is about 4% of summer baseline cooling load.

Figure 6-5. SCE estimated hourly load savings shapes



For SDG&E, the load savings shapes appear to reflect limited cooling savings. SDG&E's initial estimated load savings shape is similar to SCE's (although the scales are different). However, the adjustment only brings SDG&E's hourly load savings closer to but not above zero across most hours.

Figure 6-6. SDG&E estimated hourly load savings shapes



The weather-normalized load savings shapes for electric cooling presented here are a preliminary and exploratory attempt to establish when during the day smart thermostat savings occur. These values can inform calculation of the hourly avoided cost of energy as well as carbon impacts of savings. Here, the load savings shapes are presented as average hourly shapes for typical summer weather, but the approach offers the flexibility to look at the load savings shapes for specific days, weather conditions, and geographic areas. Though there remain details to work out with respect to the underlying experimental design, these results are suggestive of the potential of load savings shapes for this kind of measure.

7 CONCLUSIONS AND RECOMMENDATIONS

The findings from this evaluation and resulting recommendations and implications are summarized in Table 7-1.

Table 7-1: Key findings and Recommendations

Key findings	Recommendations & Implications
1. Lower than expected gross savings	Focus savings estimates on actual customer consumption of cooling and heating. Increase targeting and focus in Central Valley for customers with high cooling load. Recognize that smart thermostats have demonstrated demand response and direct load control capabilities that are not assessed in this report.
2. A majority of rebate (80%) and direct-install (60%) participants perform remote mobile app adjustments.	Provide customers with additional information that saving features can be lost if optimizing options are disabled and/or overridden by remote changes.
3. The participant population may have different consumption trends than available comparison group households. This is also supported by evidence from	Differences between participants and comparison group households point to potential increasing trends in baseload consumption among participants. The next smart thermostat evaluation should develop methods

Key findings	Recommendations & Implications
the survey. The potential for self-selection affecting savings estimates is unavoidable when randomized experimental designs are not practical.	for identifying trends in pre-installation consumption to include as a matching variable as well as other methods to minimize potential self-selection bias. Also, the current study could be updated with a new matched comparison group comprised of more recent program participants who were not available for inclusion within the existing evaluation timeframe.
4. Load savings shapes provide additional insight into what time of day smart thermostat savings occur. The shape of smart thermostat savings appears to diverge from the shape of overall cooling consumption.	Load savings shapes are an increasingly important outcome from studies like this and further research is required to move them beyond the exploratory phase. This should not only provide better estimates of load savings shapes but also provide annual savings estimates that are consistent with those obtained from other methods, including the two-stage method used in this study.
5. Customer information files do not provide a complete picture of customer dwelling types. While such information is included in Customer Information Systems dataset, there are many instances where the designation does not match what is reported in program tracking data. DNV GL has attempted to identify and match on housing types with mixed success due to the quality of the data.	DNV GL recommends that PAs provide reliable housing type information for the residential population so that future evaluations may include savings estimates that provide insights on where the measure delivers maximum savings.

8 APPENDICES

8.1 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	Smart Thermostats	81,629	35,104	0.43	0.0%	0.43
PGE	**Total**	**81,629**	**35,104**	**0.43**	**0.0%**	**0.43**
SCE	Smart Thermostats	184,820	67,401	0.36	0.0%	0.36
SCE	**Total**	**184,820**	**67,401**	**0.36**	**0.0%**	**0.36**
SCG	Smart Thermostats	185,534	43,743	0.24	0.0%	0.24
SCG	**Total**	**185,534**	**43,743**	**0.24**	**0.0%**	**0.24**
SDGE	Smart Thermostats	32,511	4,713	0.14	0.0%	0.14
SDGE	**Total**	**32,511**	**4,713**	**0.14**	**0.0%**	**0.14**
	Statewide	***484,494***	***150,962***	***0.31***	***0.0%***	***0.31***

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	Smart Thermostats	48,977	26,423	0.54	0.0%	0.60	0.75	0.60	0.75
PGE	**Total**	**48,977**	**26,423**	**0.54**	**0.0%**	**0.60**	**0.75**	**0.60**	**0.75**
SCE	Smart Thermostats	124,256	60,116	0.48	0.0%	0.67	0.89	0.67	0.89
SCE	**Total**	**124,256**	**60,116**	**0.48**	**0.0%**	**0.67**	**0.89**	**0.67**	**0.89**
SCG	Smart Thermostats	120,097	39,571	0.33	0.0%	0.65	0.90	0.65	0.90
SCG	**Total**	**120,097**	**39,571**	**0.33**	**0.0%**	**0.65**	**0.90**	**0.65**	**0.90**
SDGE	Smart Thermostats	19,570	3,859	0.20	0.0%	0.60	0.82	0.60	0.82
SDGE	**Total**	**19,570**	**3,859**	**0.20**	**0.0%**	**0.60**	**0.82**	**0.60**	**0.82**
	Statewide	***312,900***	***129,968***	***0.42***	***0.0%***	***0.65***	***0.86***	***0.65***	***0.86***

Gross Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	Smart Thermostats	0.0	0.0			
PGE	**Total**	**0.0**	**0.0**			
SCE	Smart Thermostats	0.0	0.0			
SCE	**Total**	**0.0**	**0.0**			
SCG	Smart Thermostats	0.0	0.0			
SCG	**Total**	**0.0**	**0.0**			
SDGE	Smart Thermostats	0.0	0.0			
SDGE	**Total**	**0.0**	**0.0**			
	Statewide	***0.0***	***0.0***			

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	Smart Thermostats	0.0	0.0						
PGE	**Total**	**0.0**	**0.0**						
SCE	Smart Thermostats	0.0	0.0						
SCE	**Total**	**0.0**	**0.0**						
SCG	Smart Thermostats	0.0	0.0						
SCG	**Total**	**0.0**	**0.0**						
SDGE	Smart Thermostats	0.0	0.0						
SDGE	**Total**	**0.0**	**0.0**						
	Statewide	***0.0***	***0.0***						

Gross Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	Smart Thermostats	7,992	3,013	0.38	0.0%	0.38
PGE	**Total**	**7,992**	**3,013**	**0.38**	**0.0%**	**0.38**
SCE	Smart Thermostats	8,700	725	0.08	0.0%	0.08
SCE	**Total**	**8,700**	**725**	**0.08**	**0.0%**	**0.08**
SCG	Smart Thermostats	13,261	1,020	0.08	0.0%	0.08
SCG	**Total**	**13,261**	**1,020**	**0.08**	**0.0%**	**0.08**
SDGE	Smart Thermostats	1,646	302	0.18	0.0%	0.18
SDGE	**Total**	**1,646**	**302**	**0.18**	**0.0%**	**0.18**
	Statewide	***31,599***	***5,059***	***0.16***	***0.0%***	***0.16***

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	Smart Thermostats	4,795	2,268	0.47	0.0%	0.60	0.75	0.60	0.75
PGE	**Total**	**4,795**	**2,268**	**0.47**	**0.0%**	**0.60**	**0.75**	**0.60**	**0.75**
SCE	Smart Thermostats	6,067	646	0.11	0.0%	0.70	0.89	0.70	0.89
SCE	**Total**	**6,067**	**646**	**0.11**	**0.0%**	**0.70**	**0.89**	**0.70**	**0.89**
SCG	Smart Thermostats	8,624	922	0.11	0.0%	0.65	0.90	0.65	0.90
SCG	**Total**	**8,624**	**922**	**0.11**	**0.0%**	**0.65**	**0.90**	**0.65**	**0.90**
SDGE	Smart Thermostats	989	247	0.25	0.0%	0.60	0.82	0.60	0.82
SDGE	**Total**	**989**	**247**	**0.25**	**0.0%**	**0.60**	**0.82**	**0.60**	**0.82**
	Statewide	***20,475***	***4,083***	***0.20***	***0.0%***	***0.65***	***0.81***	***0.65***	***0.81***

Gross First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	Smart Thermostats	7,583	3,191	0.42	0.0%	0.42
PGE	**Total**	**7,583**	**3,191**	**0.42**	**0.0%**	**0.42**
SCE	Smart Thermostats	17,440	6,127	0.35	0.0%	0.35
SCE	**Total**	**17,440**	**6,127**	**0.35**	**0.0%**	**0.35**
SCG	Smart Thermostats	13,282	3,977	0.30	0.0%	0.30
SCG	**Total**	**13,282**	**3,977**	**0.30**	**0.0%**	**0.30**
SDGE	Smart Thermostats	3,073	428	0.14	0.0%	0.14
SDGE	**Total**	**3,073**	**428**	**0.14**	**0.0%**	**0.14**
	Statewide	***41,378***	***13,724***	***0.33***	***0.0%***	***0.33***

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	Smart Thermostats	4,550	2,402	0.53	0.0%	0.60	0.75	0.60	0.75
PGE	**Total**	**4,550**	**2,402**	**0.53**	**0.0%**	**0.60**	**0.75**	**0.60**	**0.75**
SCE	Smart Thermostats	11,728	5,465	0.47	0.0%	0.67	0.89	0.67	0.89
SCE	**Total**	**11,728**	**5,465**	**0.47**	**0.0%**	**0.67**	**0.89**	**0.67**	**0.89**
SCG	Smart Thermostats	8,686	3,597	0.41	0.0%	0.65	0.90	0.65	0.90
SCG	**Total**	**8,686**	**3,597**	**0.41**	**0.0%**	**0.65**	**0.90**	**0.65**	**0.90**
SDGE	Smart Thermostats	1,850	351	0.19	0.0%	0.60	0.82	0.60	0.82
SDGE	**Total**	**1,850**	**351**	**0.19**	**0.0%**	**0.60**	**0.82**	**0.60**	**0.82**
	Statewide	***26,813***	***11,815***	***0.44***	***0.0%***	***0.65***	***0.86***	***0.65***	***0.86***

Gross First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	Smart Thermostats	0.0	0.0			
PGE	**Total**	**0.0**	**0.0**			
SCE	Smart Thermostats	0.0	0.0			
SCE	**Total**	**0.0**	**0.0**			
SCG	Smart Thermostats	0.0	0.0			
SCG	**Total**	**0.0**	**0.0**			
SDGE	Smart Thermostats	0.0	0.0			
SDGE	**Total**	**0.0**	**0.0**			
	Statewide	***0.0***	***0.0***			

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	Smart Thermostats	0.0	0.0						
PGE	**Total**	**0.0**	**0.0**						
SCE	Smart Thermostats	0.0	0.0						
SCE	**Total**	**0.0**	**0.0**						
SCG	Smart Thermostats	0.0	0.0						
SCG	**Total**	**0.0**	**0.0**						
SDGE	Smart Thermostats	0.0	0.0						
SDGE	**Total**	**0.0**	**0.0**						
	Statewide	***0.0***	***0.0***						

Gross First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	Smart Thermostats	743	274	0.37	0.0%	0.37
PGE	**Total**	**743**	**274**	**0.37**	**0.0%**	**0.37**
SCE	Smart Thermostats	834	66	0.08	0.0%	0.08
SCE	**Total**	**834**	**66**	**0.08**	**0.0%**	**0.08**
SCG	Smart Thermostats	1,268	93	0.07	0.0%	0.07
SCG	**Total**	**1,268**	**93**	**0.07**	**0.0%**	**0.07**
SDGE	Smart Thermostats	160	27	0.17	0.0%	0.17
SDGE	**Total**	**160**	**27**	**0.17**	**0.0%**	**0.17**
	Statewide	***3,005***	***460***	***0.15***	***0.0%***	***0.15***

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	Smart Thermostats	446	206	0.46	0.0%	0.60	0.75	0.60	0.75
PGE	**Total**	**446**	**206**	**0.46**	**0.0%**	**0.60**	**0.75**	**0.60**	**0.75**
SCE	Smart Thermostats	582	59	0.10	0.0%	0.70	0.89	0.70	0.89
SCE	**Total**	**582**	**59**	**0.10**	**0.0%**	**0.70**	**0.89**	**0.70**	**0.89**
SCG	Smart Thermostats	825	84	0.10	0.0%	0.65	0.90	0.65	0.90
SCG	**Total**	**825**	**84**	**0.10**	**0.0%**	**0.65**	**0.90**	**0.65**	**0.90**
SDGE	Smart Thermostats	96	22	0.23	0.0%	0.60	0.82	0.60	0.82
SDGE	**Total**	**96**	**22**	**0.23**	**0.0%**	**0.60**	**0.82**	**0.60**	**0.82**
	Statewide	***1,949***	***371***	***0.19***	***0.0%***	***0.65***	***0.81***	***0.65***	***0.81***

8.2 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	Smart Thermostats	0	57.5%	0.0%	11.0	985.2	89.6	89.6
SCE	Smart Thermostats	0	96.1%	0.0%	11.0	854.4	77.7	77.7
SCG	Smart Thermostats	0	100.0%	0.0%	11.0	421.0	38.3	38.3
SDGE	Smart Thermostats	0	100.0%	0.0%	11.0	225.2	20.5	20.5

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	Smart Thermostats	0	57.5%	0.0%	11.0	84.6	7.7	7.7
SCE	Smart Thermostats	0	96.1%	0.0%	11.0	9.2	0.8	0.8
SCG	Smart Thermostats	0	100.0%	0.0%	11.0	9.8	0.9	0.9
SDGE	Smart Thermostats	0	100.0%	0.0%	11.0	14.4	1.3	1.3

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	Smart Thermostats	0	57.5%	0.0%	11.0	741.5	67.4	67.4
SCE	Smart Thermostats	0	96.1%	0.0%	11.0	762.0	69.3	69.3
SCG	Smart Thermostats	0	100.0%	0.0%	11.0	380.8	34.6	34.6
SDGE	Smart Thermostats	0	100.0%	0.0%	11.0	184.4	16.8	16.8

Per Unit (Quantity) Net Energy Savings (Therms)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	Smart Thermostats	0	57.5%	0.0%	11.0	63.7	5.8	5.8
SCE	Smart Thermostats	0	96.1%	0.0%	11.0	8.2	0.7	0.7
SCG	Smart Thermostats	0	100.0%	0.0%	11.0	8.9	0.8	0.8
SDGE	Smart Thermostats	0	100.0%	0.0%	11.0	11.8	1.1	1.1

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

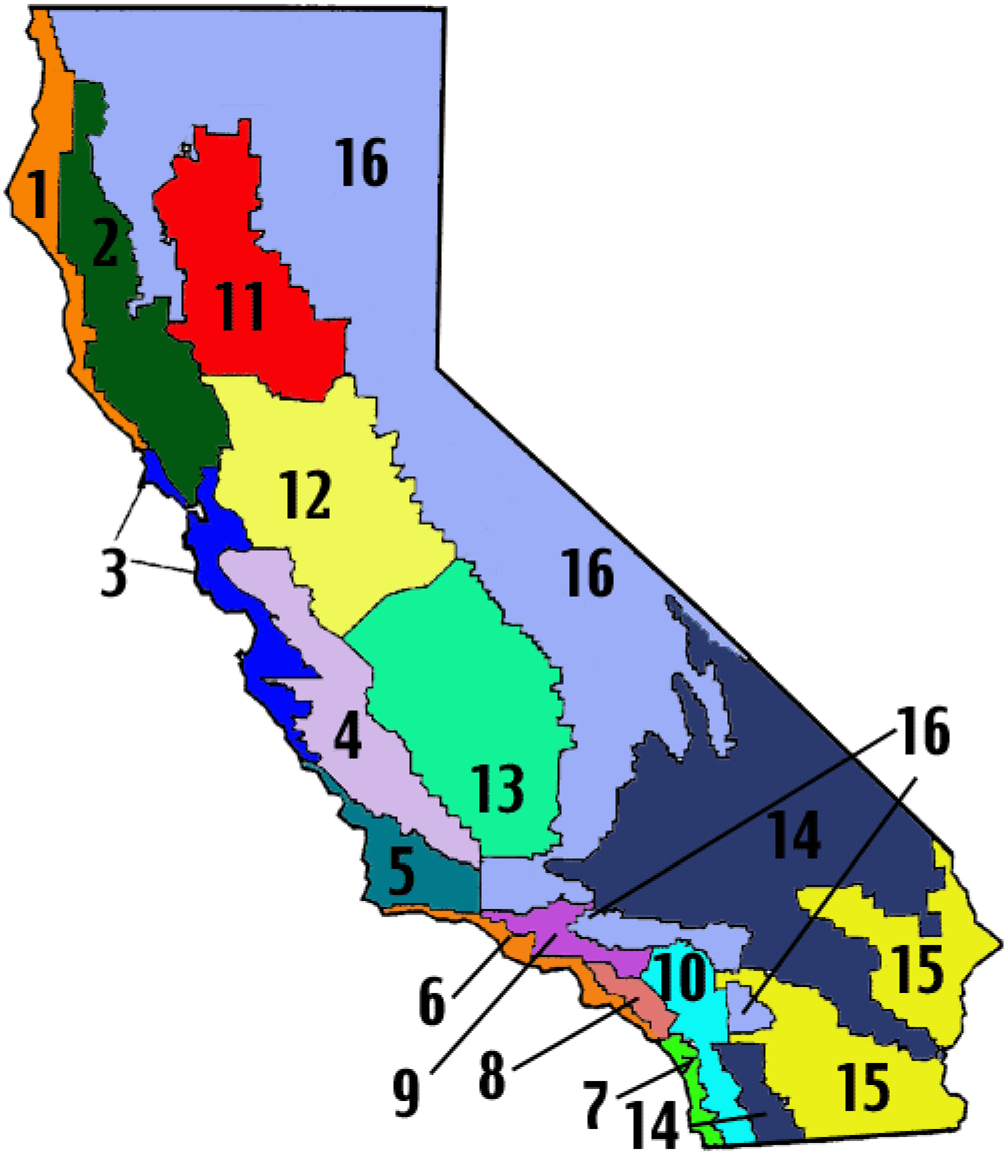
Study ID	Study Type	Study Title	CPUC Study Manager
Group A Residential Sector	Impact Evaluation	Impact Evaluation of Smart Thermostats - Program Year 2018	Peter Franzese

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
1	Multiple programs delivering smart thermostats	Lower than expected gross savings	Section 5	Focus savings estimates on actual customer consumption of cooling and heating. Increase targeting and focus in Central Valley for customers with high cooling load. Recognize that smart thermostats have demonstrated demand response and direct load control capabilities that are not assessed in this report.	All PAs	Statewide WP - SWHC039-02 Res Smart Thermostat_080119 Final DEER – Consideration for September 2020 resolution
2	Multiple programs delivering smart thermostats	A majority of rebate (80%) and direct-install (60%) participants perform remote mobile app adjustments.	Section 4	Provide customers with additional information that saving features can be lost if optimizing options are disabled and/or overridden by remote changes.	All PAs	N/A (Program design consideration)

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
3	Multiple programs delivering smart thermostats	The participant population may have different consumption trends than available comparison group households. This is also supported by evidence from the survey. The potential for self-selection affecting savings estimates is unavoidable when randomized experimental designs are not practical.	Sections 4, 5	Differences between participants and comparison group households point to potential increasing trends in baseload consumption among participants. The next smart thermostat evaluation should develop methods for identifying trends in pre-installation consumption to include as a matching variable as well as other methods to minimize potential self-selection bias. Also, the current study could be updated with a new matched comparison group comprised of more recent program participants who were not available for inclusion within the existing evaluation timeframe.	CPUC ED EM&V	Statewide WP - SWHC039-02 Res Smart Thermostat_080119 Final
4	Multiple programs delivering smart thermostats	Load savings shapes provide additional insight into what time of day smart thermostat savings occur. The shape of smart thermostat savings appears to diverge from the shape of overall cooling consumption.	Section 6	Load savings shapes are an increasingly important outcome from studies like this and further research is required to move them beyond the exploratory phase. This should not only provide better estimates of load savings shapes but also provide annual savings estimates that are consistent with those obtained from other methods, including the two-stage method used in this study.	All PAs, CPUC ED	Statewide WP - SWHC039-02 Res Smart Thermostat_080119 Final DEER – Consideration for September 2020 resolution

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
5	Multiple programs delivering smart thermostats	Customer information files do not provide a complete picture of customer dwelling types. While such information is included in Customer Information Systems dataset, there are many instances where the designation does not match what is reported in program tracking data. DNV GL has attempted to identify and match on housing types with mixed success due to the quality of the data.		DNV GL recommends that PAs provide reliable housing type information for the residential population so that future evaluations may include savings estimates that provide insights on where the measure delivers maximum savings.	All PAs	

8.4 Appendix D: Climate zone



8.5 Appendix E: Matching

The quasi-experimental design that DNV GL used in this study involved the identification of comparison group customers that served as matches for smart thermostat participants. This section provides results from the 3-phase matching that DNV GL undertook to select such matched comparison households. Tests of balance between participant and selected comparison group customers show improvements in the condition of matching with each phase. Matching conditions from the third-phase of matching, which provided the final matched comparison group customers, show groups which are very well-balanced.

8.5.1 First-phase matching results

Table 8-1 provides values of the metrics used to test balance. These metrics are computed based on total consumption of participants and selected candidate matches before and after matching. In general, standardized mean differences and the ratios of variance of total consumption for the matched groups show that the selected 10:1 matches are balanced well enough. Standardized differences for the matched groups are all well below 0.2 (are no higher than 0.06) and the ratio of variances have generally improved although some of the ratios indicate further second-phase matching is required to generate better 1:1 matches.

Table 8-1. First-phase matching test of balance metrics

PA	Fuel	Standardized Mean Difference		Variance Ratio	
		Unmatched	Matched	Unmatched	Matched
PG&E	dual - electric	0.02	0.05	7	2
	dual - gas	0.04	0.05	4	3
	electric-only	0.09	0.05	41	3
	gas-only	0.04	0.04	10	5
SCE	dual - electric	0.21	0.03	1	1
	electric-only	0.31	0.02	1	1
SCG	dual - gas	0.03	0.04	1	1
	gas-only	0.07	0.05	1	1
SDG&E	dual - electric	0.27	0.06	1	1
	dual - gas	0.10	0.05	1	1
	electric-only	0.09	0.05	14	15
	gas-only	0.06	0.04	1	1

8.5.2 Second-phase matching results

The metrics used to test the condition of balance indicate that the selected 1:1 matches in this phase of matching are well-balanced (Table 8-2). As in the first-phase matching, total consumption of the matched groups was used to compute the test of balance metrics. Most standardized mean differences are 0.01 and the ratios of variance of total consumption between matched groups are close to 1.

Table 8-2. Second-phase matching test of balance metrics

PA	Fuel	Standardized Mean Difference	Variance Ratio
PG&E	dual - electric	0.01	0.8
	dual - gas	-0.01	0.8
	electric-only	0.01	0.8
	gas-only	0.08	0.9
SCE	dual - electric	0.02	0.9
	electric-only	-0.02	0.7
SCG	dual - gas	0.00	1.0

PA	Fuel	Standardized Mean Difference	Variance Ratio
	gas-only	0.01	0.9
SDG&E	dual - electric	-0.04	0.8
	dual - gas	-0.02	0.9
	electric-only	-0.03	0.9

Plots of matched daily average weekday and weekend electric (kWh) and gas (therm) values also indicate the conditions of balance between participant and their comparison groups. Further, density plots of total consumption and 6 p.m. kWh values for matched groups also reflect the status of matching.

Figure 8-1 presents daily average weekday and weekend values of kWh and therms for matched samples of PG&E. The panels in the figure reflect the 1:1 matched samples are well-balanced with respect to these values.

Figure 8-1. PG&E daily average weekday and weekend values of matched variables

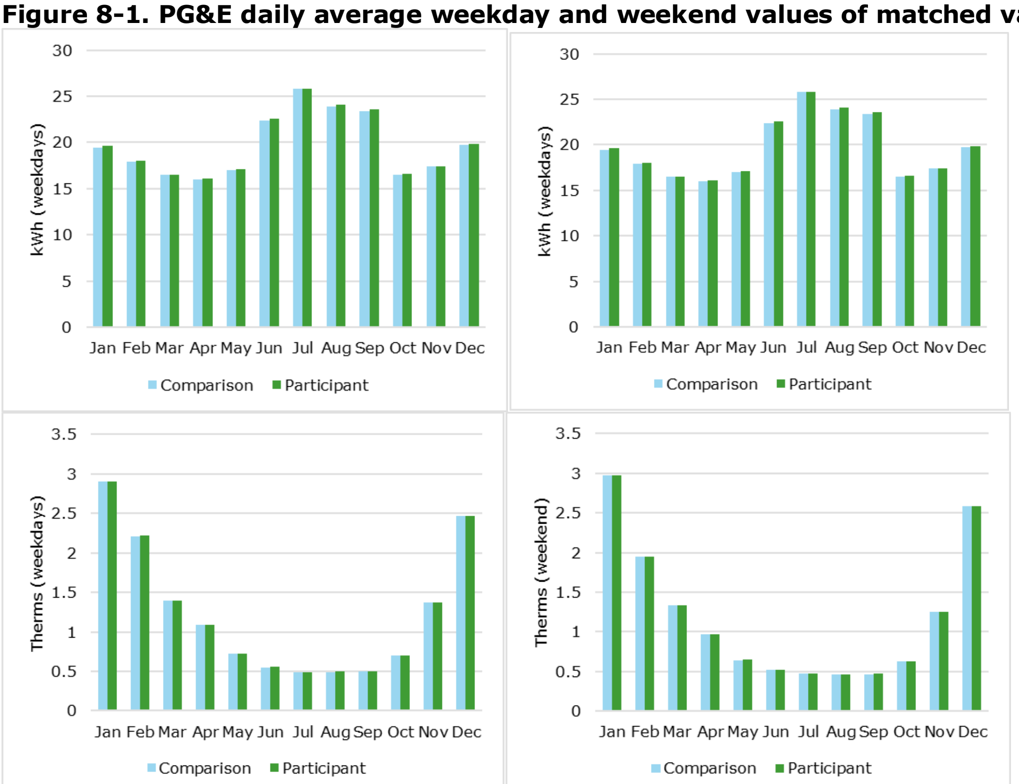


Figure 8-2 presents the density plots of total kWh, total therms, and 6 p.m. kWh values for the same matched households. Although balance is not perfect, the figure shows groups that are generally well-balanced.

Figure 8-2. Distribution of PG&E's matched electric and gas variables

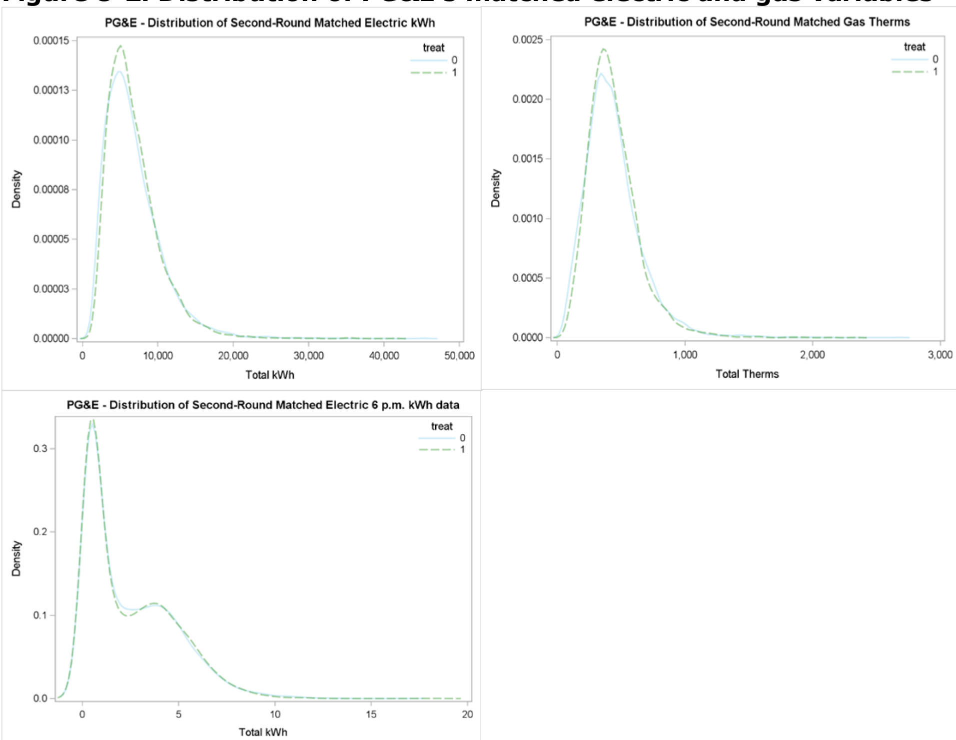


Figure 8-3 shows plots of daily average weekday and weekend kWh values for matched SCE participant and comparison group customers. The panels indicate samples that are well matched with respect to these variables, which were also used in matching.

Figure 8-3. SCE daily average weekday and weekend values of matched variables

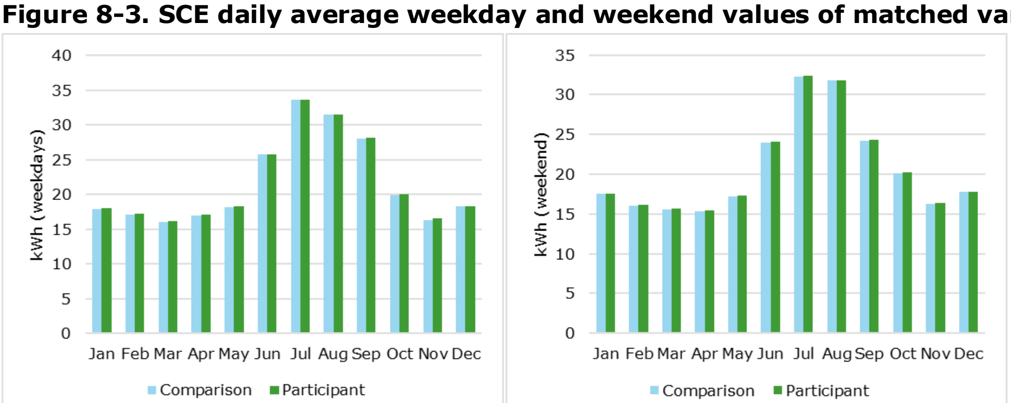
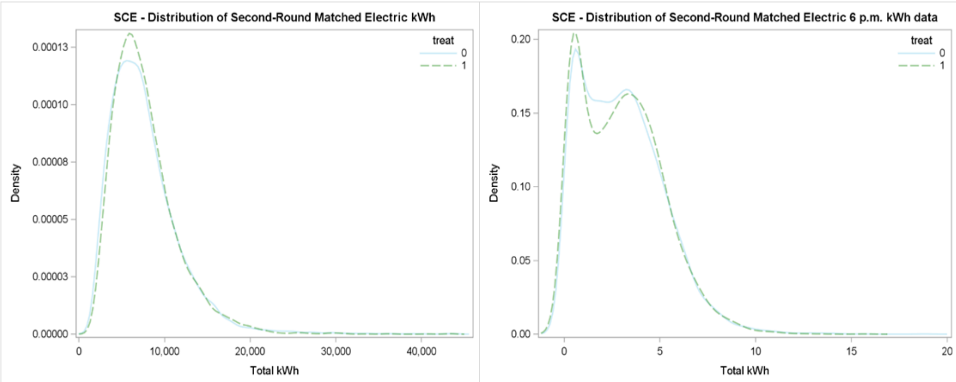


Figure 8-4 presents the distribution of SCE's total consumption and 6 p.m. kWh values for the matched households. These indicate a condition of general good balance for the two matched groups.

Figure 8-4. Distribution of SCE's matched electric variables



Plots of phase 2 matched weekday and weekend daily average therms for SCG are presented in Figure 8-5. The panels indicate groups that are well-matched with respect to these variables.

Figure 8-5. SCG daily average weekday and weekend values of matched variables

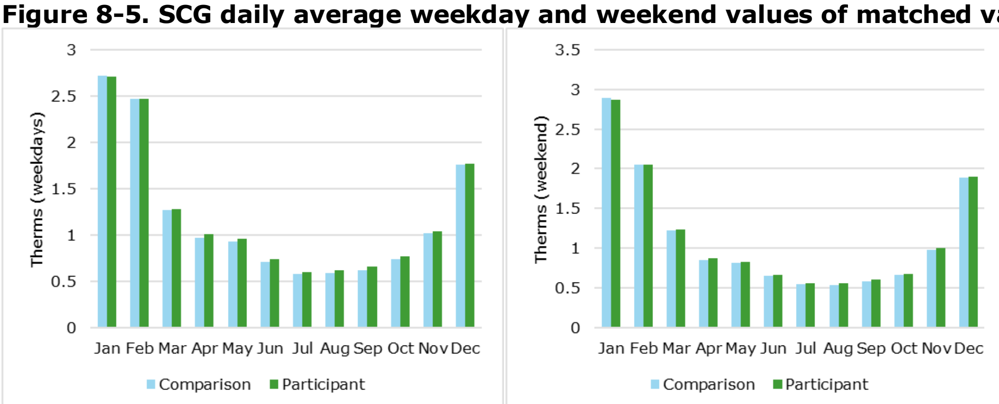
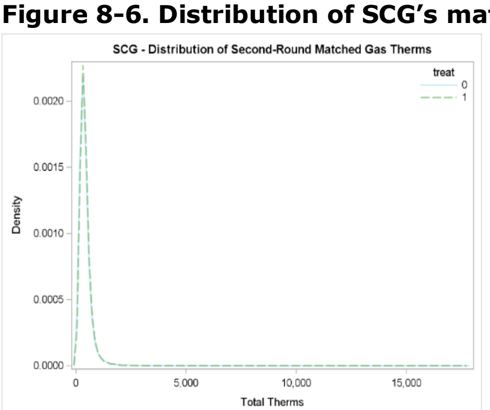


Figure 8-6 further indicates that these SCG's participant and comparison group samples are well-balance.

Figure 8-6. Distribution of SCG's matched gas variables



The final set of figures present phase 2 matches for SDG&E. Figure 8-7 shows that SDG&E's participant and comparison group matches are well-balanced with respect to daily average weekday and weekend kWh and therm values.

Figure 8-7. SDG&E daily average weekday and weekend values of matched variables

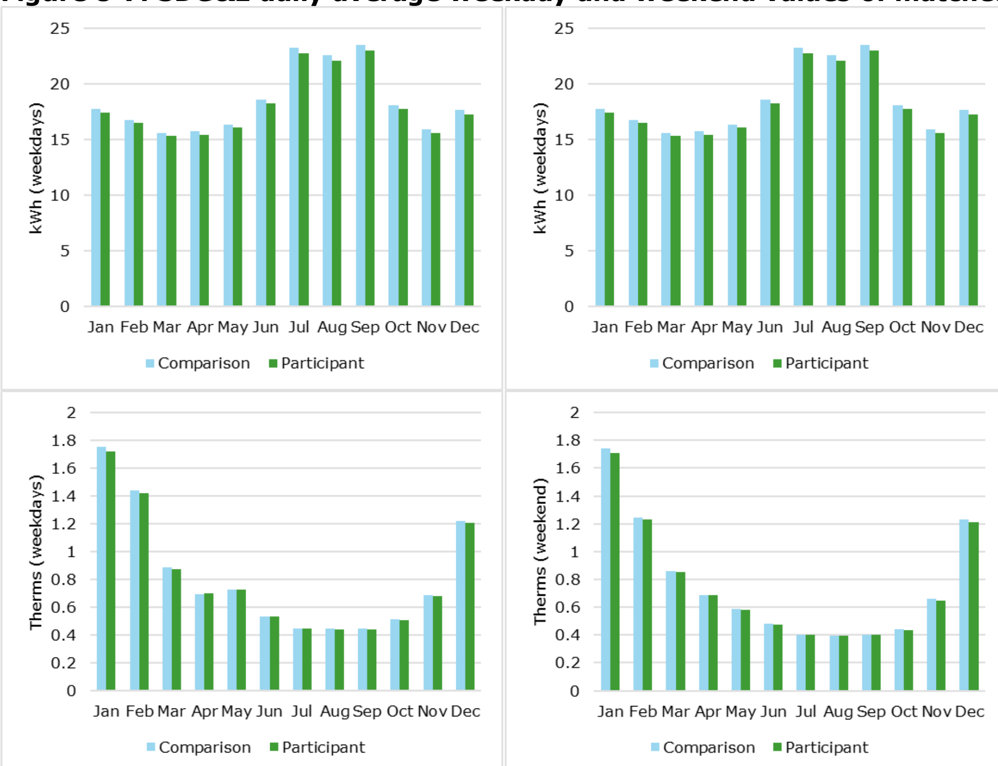
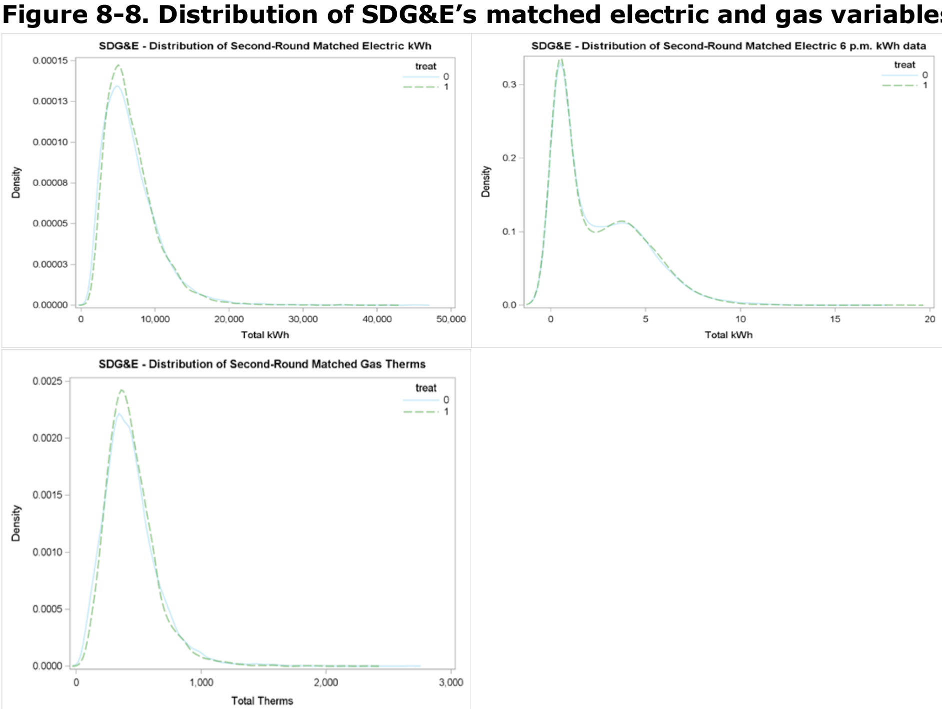


Figure 8-8 also shows the condition of phase 2 matching for SDG&E. The panels show that SDG&E's total kWh, total therms and 6 p.m. kWh values for participant and comparison groups are well-balanced.

Figure 8-8. Distribution of SDG&E's matched electric and gas variables



8.5.3 Third-phase matching results

Third-phase matching tests of balance indicate samples that are well-balanced for both electric and gas, and all PAs. Table 8-3 provides the metrics used to test balance for all PAs and fuels. The standardized difference of total consumption and the ratio of the variance of total consumption for matched participant and comparison group customers reflect samples that are well-balanced in all cases.

Table 8-3. Third-phase matching test of balance metrics

PA	Fuel	Standardized Mean Difference	Variance Ratio
PG&E	electric	0.0	1.0
	gas	0.0	1.0
SCE	electric	0.0	1.0
SCG	gas	0.0	1.0
SDG&E	electric	0.0	1.0
	gas	0.0	1.0

The condition of matches is also illustrated using plots of average monthly values of energy consumption and density plots of total energy consumption for matched pairs. Figure 8-9 presents matched average monthly kWh and therms for PG&E's final matched pair. These indicate matches are well-balanced in final samples used in the analysis. Figure 8-10 shows a similar situation based on the distribution of matched total electricity and gas consumption for the two groups.

Figure 8-9. PG&E electric and gas average monthly matched consumption

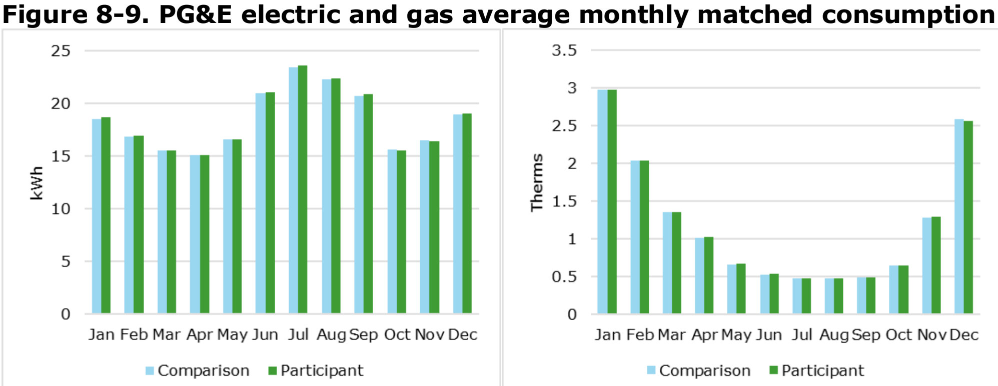


Figure 8-10. Distribution of PG&E's final matched electric and gas variables

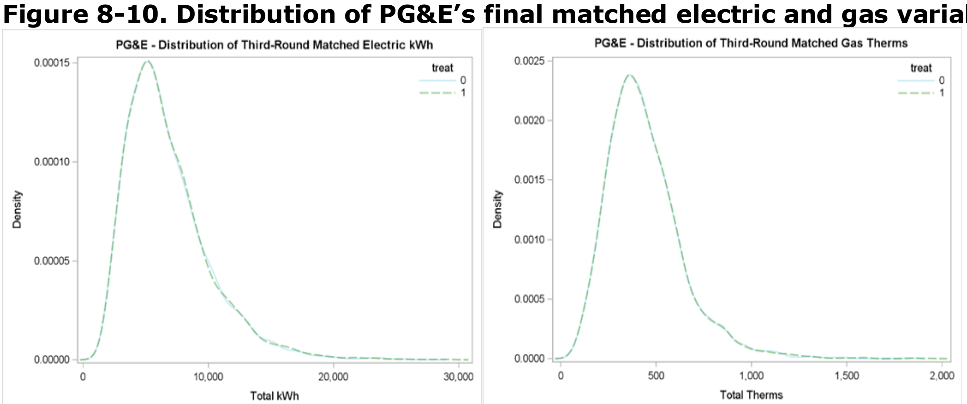


Figure 8-11 provides matched average monthly kWh for SCE and average monthly therms for SCG. Both panels indicate samples that are well-balanced. Figure 8-12 presents the distribution of total kWh and total therms for SCE and SCG respectively and indicate final matches used in the analysis that are also well-balanced.

Figure 8-11. SCE electric and SCG gas average monthly matched consumption

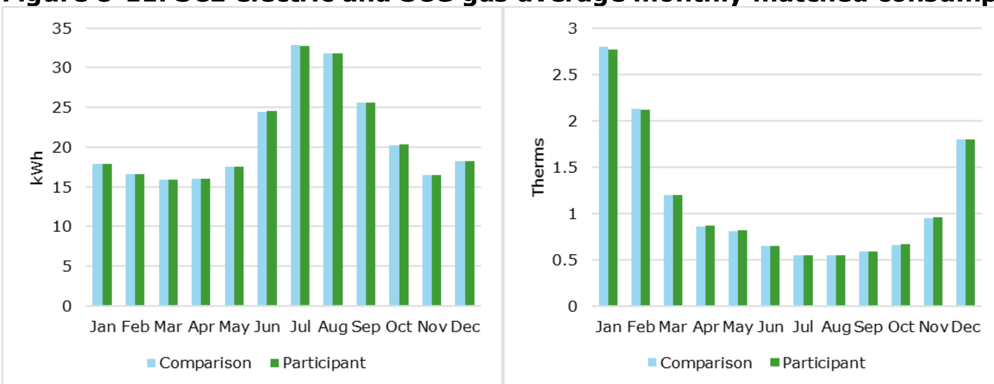
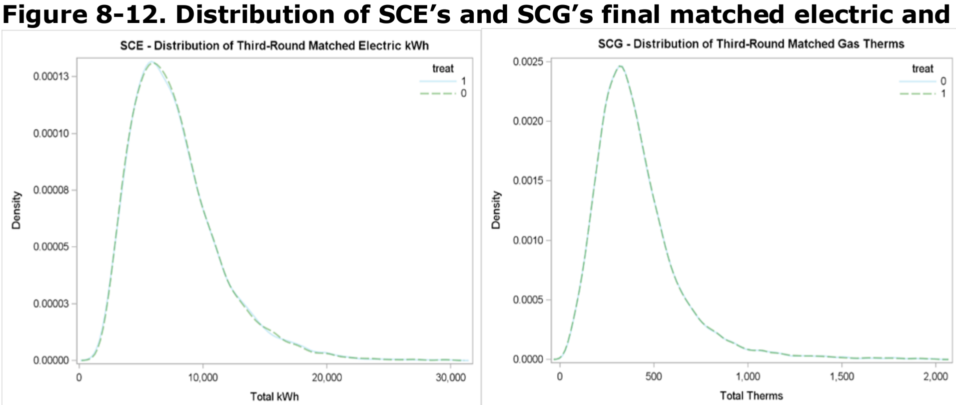


Figure 8-12. Distribution of SCE's and SCG's final matched electric and gas variables



The analogous findings are presented in Figure 8-13 and Figure 8-14 for SDG&E. Similar to the other PAs, these figures indicate SDG&E's matched sample used in the analysis reflect good balance.

Figure 8-13. SDG&E electric and gas average monthly matched consumption

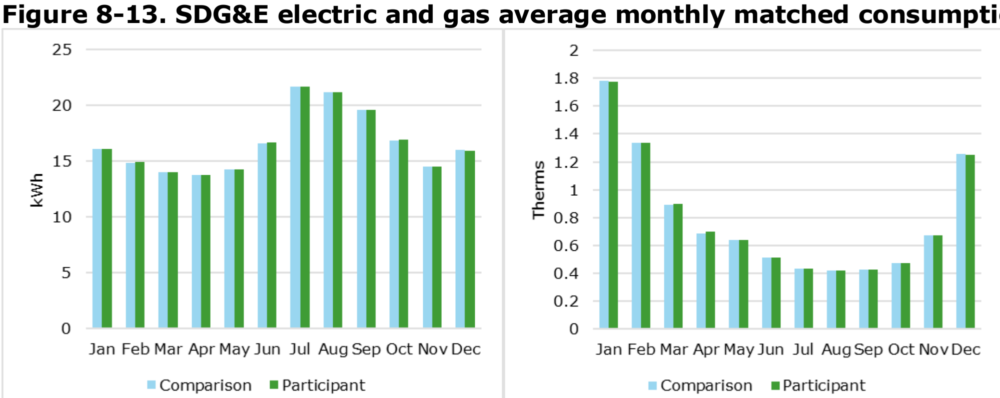
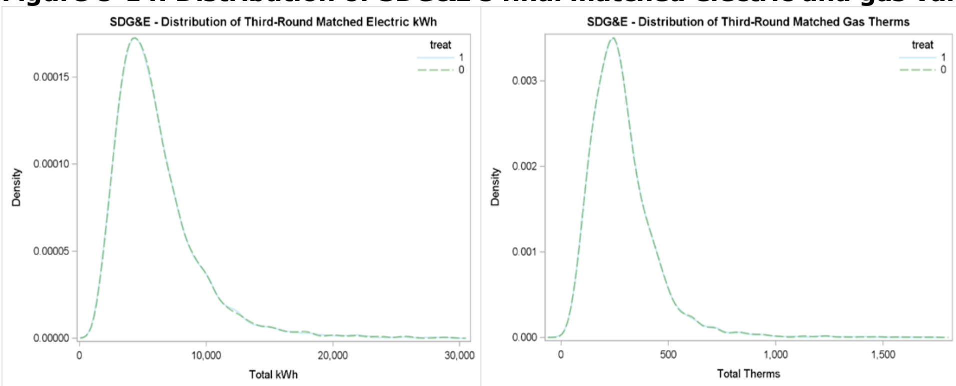


Figure 8-14. Distribution of SDG&E's final matched electric and gas variables



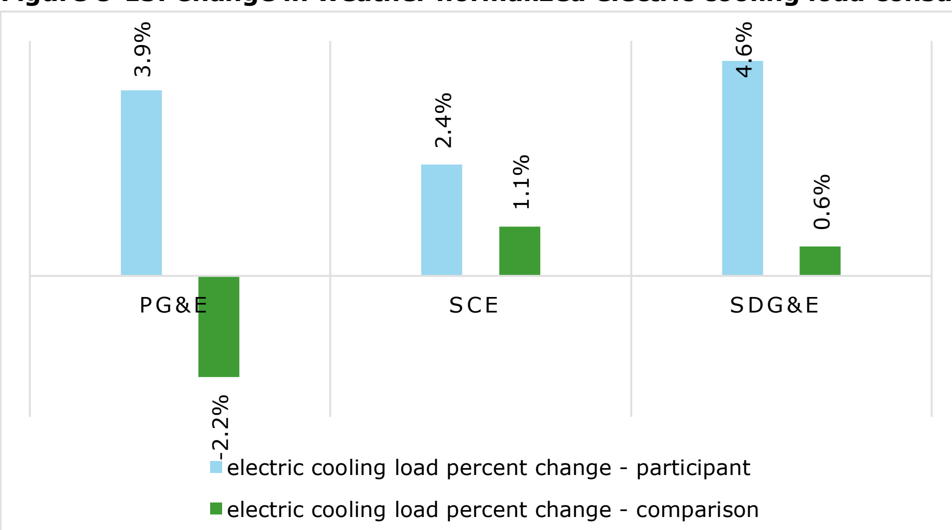
8.6 Appendix F: Site-level model results

Site-level models provide energy use that reflect typical meteorological year weather conditions. DNV GL estimated weather normalized annual electric cooling, electric heating, and gas heating load in the pre- and post-installation periods using optimal degree-day base points estimated for each site. Optimal degree day base point estimates reflect the temperatures at which each household uses heating or cooling. Such points are a function of the level of insulation, solar gains and thermostat set points at each site.

Pre-post normalized cooling and heating load differences reflect unadjusted gross changes and indicate the extent of weather-normalized energy use adjustments in the post-installation period. If post-period unadjusted gross changes are positive, they reflect energy use reductions after controlling for the effect of weather changes. These changes include the effect of smart thermostat use and other non-smart thermostat related changes.

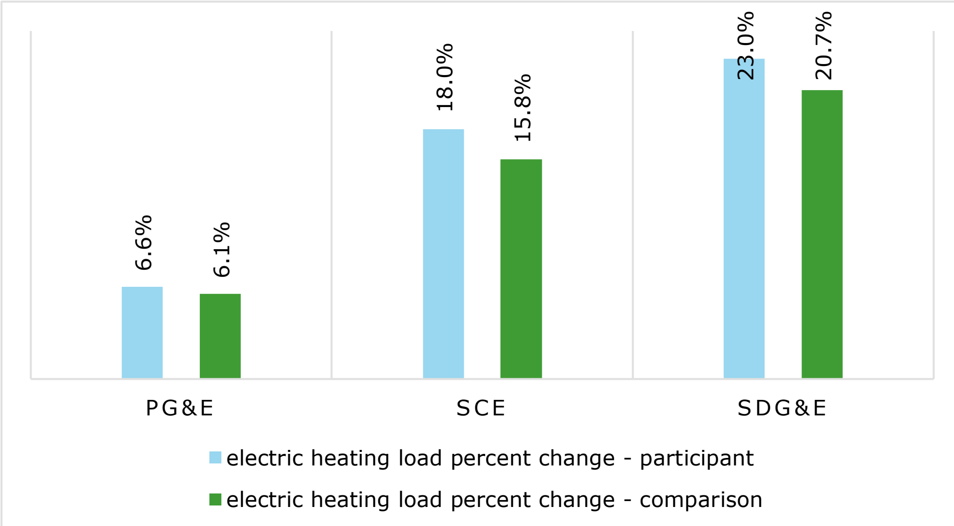
Figure 8-15 provides a comparison of percent changes in annual weather normalized electric cooling load from pre- to post-installation period for participants and comparison groups by PA. Unadjusted gross electric cooling load reductions range from 2.4% (SCE) to 4.6% (SDG&E) for participants. The percent changes for the comparison group show an increase in weather normalized electric cooling load of 2.2% for PG&E, and reductions for SCE and SDG&E that are lower than they are for participants.

Figure 8-15. Change in weather normalized electric cooling load consumption



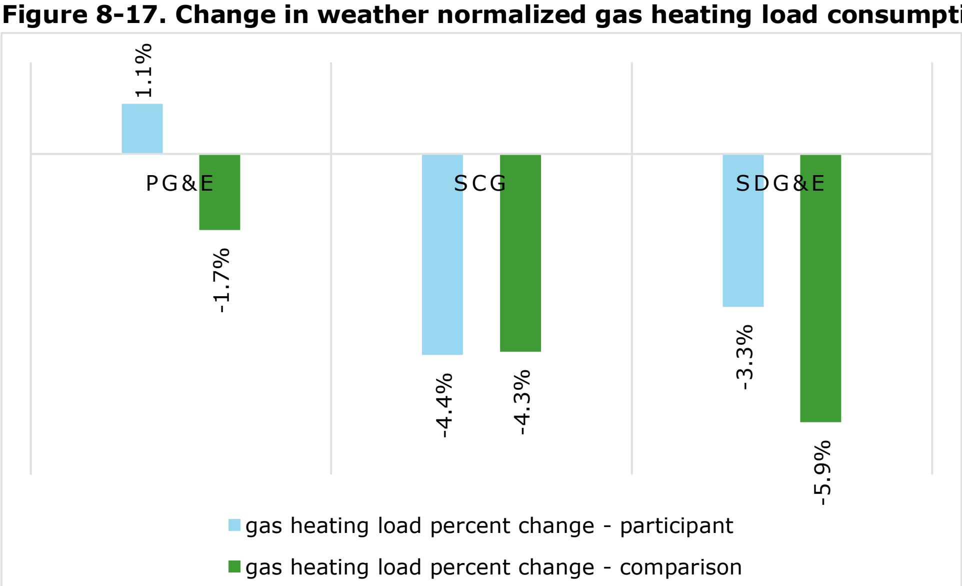
Unadjusted gross electric heating load changes are presented in Figure 8-16. These changes also reflect electric heating load reductions that are greater for participants than for comparison group customers for each PA. For example, SCE's participants weather normalized electric heating load decreased by 18% from pre- to post-installation while that for the comparison group decreased by 15.8% in the post period. Similar to electric cooling load, weather normalized electric heating load reflect unadjusted gross savings for participants of each PA.

Figure 8-16. Change in weather normalized electric heating load consumption



Percent weather normalized heating load changes from pre- to post-installation period are presented in Figure 8-17. These changes reflect unadjusted gross gas heating savings for all PG&E and SDG&E. PG&E's participant reduced gas heating load use from pre- to post while the customers to whom they are compared increased such use. While SDG&E's customers had higher weather normalized gas heating savings from pre- to the post-installation period, this increase was lower than that experienced by the customers to whom they are compared. SCG participants' weather normalized post period gas heating load was higher by the same amount as the comparison group's.

Figure 8-17. Change in weather normalized gas heating load consumption



8.7 Appendix G: Second-stage difference-in-difference model results

Table 8-4 to Table 8-10. Gas normalized annual heating load DID model

present estimates from second-stage difference-in-difference (DID) models used in the evaluation. The DID intercept columns provide the estimate of comparison group pre-post change. The DID slope columns provide the estimate of savings for participants in the post period (savings are positive). The baseline intercept provides comparison group post-period consumption and the baseline slope provides the difference between comparison and participant in the post period (increase in consumption is positive).

Table 8-4. Electric normalized annual whole home consumption DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	279	73.1	68.80	0.29	-113.5	94.22	0.23	6,672.0	274.53	0.00	231.2	344.12	0.50
3	1,589	4.3	29.80	0.89	-75.1	36.92	0.04	5,319.0	98.49	0.00	192.4	120.89	0.11
4	1,307	90.7	34.49	0.01	-132.4	43.61	0.00	6,100.0	124.04	0.00	203.2	150.04	0.18
5	61	212.4	121.97	0.09	-117.8	207.39	0.57	4,842.0	401.33	0.00	643.0	511.53	0.21
11	221	-41.7	134.28	0.76	19.0	160.46	0.91	8,878.0	366.15	0.00	-3.8	447.32	0.99
12	1,342	66.6	42.06	0.11	-150.8	50.43	0.00	7,381.0	126.20	0.00	272.5	154.78	0.08
13	381	69.1	88.10	0.43	121.6	107.78	0.26	9,273.0	241.29	0.00	-118.5	298.00	0.69
16	20	-6.5	219.36	0.98	476.9	332.91	0.16	5,235.0	834.07	0.00	19.4	1314.99	0.99
SCE													
6	722	89.0	53.85	0.10	-47.4	65.77	0.47	6,684.0	188.21	0.00	-6.2	220.59	0.98
8	1,574	195.8	35.17	0.00	-220.3	43.99	0.00	6,831.0	110.84	0.00	281.8	136.32	0.04
9	1,608	99.8	37.74	0.01	-154.4	48.38	0.00	7,645.0	136.08	0.00	313.2	165.74	0.06
10	1,305	83.2	41.43	0.04	-151.7	52.70	0.00	8,270.0	132.66	0.00	194.1	161.85	0.23
13	109	-43.2	139.54	0.76	-11.5	196.68	0.95	9,617.0	387.80	0.00	-116.6	511.35	0.82
14	143	-19.0	124.41	0.88	-53.2	159.44	0.74	8,404.0	374.54	0.00	267.0	467.82	0.57
15	124	145.9	212.31	0.49	62.4	260.74	0.81	10,210.0	575.32	0.00	127.1	750.18	0.87
16	54	-172.3	128.89	0.18	-235.1	200.58	0.24	6,549.0	537.45	0.00	542.1	768.70	0.48
SDG&E													
6	424	357.1	80.90	0.00	-32.3	104.76	0.76	6,764.0	255.81	0.00	102.5	324.45	0.75
7	2,695	111.2	23.37	0.00	-43.4	31.78	0.17	5,375.0	77.39	0.00	161.1	94.01	0.09
8	252	617.2	123.07	0.00	-221.6	157.92	0.16	7,345.0	385.54	0.00	299.7	475.88	0.53
10	1,298	107.1	37.73	0.00	-85.3	51.03	0.09	6,248.0	115.37	0.00	192.6	145.03	0.18

Table 8-5. Electric normalized annual baseload DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	274	107.0	80.06	0.18	-74.3	103.29	0.47	5,889.0	258.16	0.00	230.6	323.66	0.48
3	1,561	48.1	26.10	0.07	-80.7	33.10	0.01	4,723.0	92.54	0.00	170.4	112.60	0.13
4	1,293	113.0	28.36	0.00	-149.1	37.33	0.00	5,361.0	110.27	0.00	175.7	134.75	0.19
5	60	179.0	117.82	0.13	-107.1	166.05	0.52	4,434.0	356.82	0.00	636.4	460.99	0.17
11	219	155.1	104.98	0.14	-153.0	126.05	0.23	6,253.0	321.55	0.00	191.7	383.38	0.62
12	1,325	107.6	32.81	0.00	-195.3	41.29	0.00	5,885.0	109.95	0.00	272.7	134.11	0.04
13	375	177.3	74.87	0.02	-75.2	90.87	0.41	5,897.0	184.86	0.00	92.4	228.97	0.69
16	18	163.8	270.89	0.55	193.9	344.33	0.58	4,206.0	770.47	0.00	208.9	1264.00	0.87
SCE													
6	717	176.6	54.27	0.00	-100.8	64.66	0.12	5,744.0	166.53	0.00	-18.6	195.53	0.92
8	1,544	216.6	31.12	0.00	-169.3	37.67	0.00	5,267.0	93.73	0.00	276.3	115.08	0.02
9	1,585	219.7	32.22	0.00	-155.8	39.73	0.00	5,561.0	106.42	0.00	320.5	132.45	0.02
10	1,287	271.6	34.26	0.00	-122.0	42.90	0.00	5,855.0	105.98	0.00	163.5	129.67	0.21
13	109	252.4	133.08	0.06	-170.5	169.84	0.32	6,177.0	313.76	0.00	15.5	396.04	0.97
14	139	124.9	101.30	0.22	-167.3	128.27	0.19	5,366.0	254.42	0.00	371.0	333.15	0.27
15	117	119.9	138.02	0.39	-85.7	176.20	0.63	6,056.0	422.90	0.00	435.7	523.07	0.41
16	51	48.4	131.32	0.71	-192.3	174.71	0.27	4,413.0	427.92	0.00	517.3	640.27	0.42
SDG&E													
6	408	325.2	73.43	0.00	-41.9	95.33	0.66	5,660.0	226.32	0.00	-15.4	287.88	0.96
7	2,608	236.3	20.70	0.00	-22.7	27.27	0.40	4,426.0	67.88	0.00	133.9	82.64	0.11
8	243	462.1	110.93	0.00	-174.2	131.28	0.19	5,921.0	326.78	0.00	169.9	406.78	0.68
10	1,256	317.1	31.71	0.00	-92.9	41.91	0.03	4,893.0	95.91	0.00	201.7	120.69	0.09

Table 8-6. Electric normalized annual electric cooling load DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	222	-2.5	15.27	0.87	50.3	23.30	0.03	513.0	48.59	0.00	0.3	60.13	1.00
3	1,408	25.1	10.76	0.02	-25.8	17.07	0.13	279.0	33.28	0.00	66.3	45.65	0.15
4	940	12.3	9.80	0.21	25.0	13.09	0.06	530.0	24.99	0.00	7.6	29.94	0.80
5	56	-23.5	12.92	0.12	30.8	18.36	0.14	232.0	118.81	0.07	-55.0	127.94	0.67
11	194	6.7	49.52	0.89	84.2	68.57	0.22	2,208.0	122.38	0.00	-26.8	147.59	0.86
12	1,021	32.8	14.09	0.02	21.7	18.44	0.24	1,183.0	38.68	0.00	87.0	47.94	0.07
13	357	24.5	45.27	0.59	90.0	57.91	0.12	3,012.0	99.47	0.00	-37.4	119.70	0.75
16	17	233.1	99.50	0.04	32.0	162.64	0.85	480.0	164.42	0.01	418.1	509.33	0.43
SCE													
6	494	67.6	18.97	0.00	58.2	26.80	0.03	841.0	60.65	0.00	24.5	72.71	0.74
8	1,152	81.3	16.00	0.00	-18.8	20.97	0.37	1,443.0	37.90	0.00	67.1	47.52	0.16
9	1,254	74.9	17.56	0.00	4.3	23.51	0.85	1,898.0	44.93	0.00	68.1	55.00	0.22
10	1,059	-33.5	18.60	0.07	5.6	24.80	0.82	2,311.0	49.56	0.00	23.9	61.16	0.70
13	97	-217.0	72.43	0.00	160.9	99.90	0.11	3,245.0	196.55	0.00	-144.6	242.77	0.55
14	126	4.9	61.13	0.94	96.5	83.31	0.25	2,702.0	168.07	0.00	15.6	204.02	0.94
15	107	-50.0	123.91	0.69	113.1	158.09	0.48	4,478.0	348.51	0.00	295.5	436.04	0.50
16	39	-111.4	53.42	0.04	77.2	107.87	0.48	2,178.0	212.31	0.00	137.0	314.81	0.66
SDG&E													
6	268	144.2	35.13	0.00	12.4	48.81	0.80	1,057.0	79.60	0.00	120.7	103.90	0.25
7	1,727	27.3	10.24	0.01	2.4	14.57	0.87	824.0	26.89	0.00	63.4	33.56	0.06
8	171	148.9	39.12	0.00	73.4	55.59	0.19	1,508.0	112.56	0.00	90.0	138.09	0.52
10	793	11.9	16.75	0.48	23.6	22.78	0.30	1,189.0	39.81	0.00	51.3	51.22	0.32

Table 8-7. Electric normalized annual electric heating load DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	230	64.0	40.66	0.12	-16.6	45.20	0.71	645.0	74.95	0.00	-16.8	88.08	0.85
3	1,106	59.4	11.23	0.00	-2.4	15.49	0.87	583.0	21.47	0.00	26.5	29.39	0.37
4	1,061	50.4	12.99	0.00	10.3	17.57	0.56	538.0	28.57	0.00	31.2	38.19	0.41
5	48	96.9	89.53	0.29	-58.5	102.73	0.57	364.0	67.29	0.00	22.2	92.75	0.81
11	189	20.8	35.25	0.56	42.5	44.23	0.34	662.0	89.50	0.00	-127.8	96.99	0.19
12	1,095	59.0	12.57	0.00	11.6	17.16	0.50	620.0	25.81	0.00	-25.1	33.68	0.46
13	332	44.0	21.71	0.04	23.4	37.91	0.54	569.0	48.31	0.00	52.0	82.88	0.53
16	18	-76.3	113.21	0.52	329.8	137.57	0.05	1,030.0	325.20	0.01	-45.1	465.64	0.92
SCE													
6	621	32.1	20.29	0.11	13.4	25.22	0.60	526.0	27.21	0.00	-93.4	34.99	0.01
8	1,411	46.2	14.43	0.00	-15.5	17.41	0.37	435.0	22.06	0.00	-54.3	25.47	0.03
9	1,439	37.1	14.11	0.01	-4.9	19.33	0.80	443.0	20.95	0.00	-59.2	24.22	0.01
10	1,217	29.8	16.15	0.07	17.2	24.45	0.48	377.0	14.85	0.00	33.8	22.62	0.14
13	102	9.6	49.66	0.85	20.4	58.50	0.73	504.0	100.33	0.00	-52.5	116.98	0.65
14	118	46.5	19.27	0.02	15.2	36.60	0.68	507.0	61.77	0.00	-46.0	75.14	0.54
15	122	119.4	40.08	0.01	-1.9	82.33	0.98	283.0	33.56	0.00	107.0	71.20	0.14
16	47	54.0	22.84	0.03	22.6	53.41	0.68	330.0	53.27	0.00	120.8	76.89	0.12
SDG&E													
6	351	64.9	25.76	0.01	-35.8	34.50	0.30	438.0	35.80	0.00	-21.1	44.91	0.64
7	2,271	61.9	18.64	0.00	-30.1	20.84	0.15	439.0	18.55	0.00	-29.5	21.73	0.18
8	232	54.5	29.51	0.07	5.9	38.85	0.88	349.0	25.53	0.00	114.0	46.72	0.02
10	1,160	3.0	20.51	0.88	48.4	26.64	0.07	504.0	25.37	0.00	-37.2	33.37	0.26

Table 8-8. Gas normalized annual whole home consumption DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	271	-15.9	5.48	0.00	12.4	7.13	0.08	510.0	17.76	0.00	-13.4	21.29	0.53
3	1,584	-18.3	2.59	0.00	7.7	3.35	0.02	486.0	8.57	0.00	-1.4	10.21	0.89
4	1,373	12.3	2.47	0.00	9.0	3.26	0.01	437.0	8.31	0.00	-1.3	9.82	0.90
11	412	-19.7	3.84	0.00	-0.5	4.98	0.92	461.0	14.84	0.00	9.7	17.31	0.58
12	1,891	-9.7	2.08	0.00	-3.4	2.63	0.20	469.0	7.76	0.00	2.2	9.05	0.81
13	312	-21.4	4.49	0.00	7.8	5.79	0.18	422.0	15.68	0.00	-2.6	18.38	0.89
SCG													
5	106	7.7	10.65	0.47	-7.9	13.08	0.55	438.0	27.92	0.00	28.4	33.99	0.40
6	1,262	-18.7	3.64	0.00	-6.5	4.44	0.14	465.0	12.78	0.00	4.4	14.97	0.77
8	2,256	-9.0	1.94	0.00	-2.8	2.43	0.25	376.0	6.22	0.00	3.9	7.41	0.60
9	12,232	-22.0	1.15	0.00	-9.0	1.39	0.00	463.0	3.66	0.00	7.7	4.32	0.07
10	1,674	-11.0	2.26	0.00	-3.8	2.80	0.17	393.0	6.03	0.00	6.5	7.29	0.37
13	201	5.2	4.82	0.28	11.5	6.31	0.07	421.0	19.62	0.00	-2.8	22.81	0.90
14	146	-16.2	7.16	0.02	1.8	8.75	0.84	497.0	22.28	0.00	4.1	26.58	0.88
15	237	-5.0	6.24	0.42	9.1	8.23	0.27	310.0	18.51	0.00	-6.5	22.87	0.78
16	696	8.0	3.83	0.04	-4.2	4.58	0.36	448.0	12.16	0.00	3.7	14.32	0.80
SDG&E													
7	2,502	-20.3	1.79	0.00	-3.2	2.39	0.19	330.0	5.27	0.00	14.4	6.55	0.03
10	1,339	-21.9	2.52	0.00	-4.2	3.37	0.21	340.0	6.74	0.00	13.4	8.66	0.12

Table 8-9. Gas normalized annual baseload DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	253	5.6	3.13	0.07	0.4	4.58	0.94	186.0	7.48	0.00	8.5	9.58	0.38
3	1,454	4.2	1.48	0.00	0.2	1.96	0.92	218.0	4.21	0.00	1.6	5.24	0.75
4	1,285	7.4	1.50	0.00	2.3	1.92	0.23	182.0	3.95	0.00	1.2	4.83	0.81
11	392	1.8	2.19	0.40	3.5	2.94	0.23	192.0	9.68	0.00	-5.0	11.16	0.65
12	1,797	6.0	1.25	0.00	-5.2	1.51	0.00	179.0	3.21	0.00	3.0	3.95	0.45
13	302	0.6	2.60	0.81	3.4	3.21	0.28	164.0	7.53	0.00	-2.6	8.77	0.77
SCG													
5	101	5.4	5.46	0.33	-3.2	7.21	0.66	233.0	19.22	0.00	17.8	24.04	0.46
6	1,210	15.0	2.63	0.00	-3.7	3.15	0.24	244.0	7.63	0.00	3.9	9.13	0.67
8	2,191	7.3	1.28	0.00	2.5	1.71	0.14	209.0	3.82	0.00	0.4	4.67	0.93
9	11,731	7.2	0.70	0.00	-1.9	0.91	0.04	244.0	2.44	0.00	7.6	2.90	0.01
10	1,621	4.8	1.41	0.00	-1.9	1.83	0.31	212.0	4.04	0.00	1.5	4.92	0.76
13	198	5.9	2.81	0.04	1.4	3.94	0.73	184.0	10.70	0.00	0.7	12.39	0.96
14	142	9.5	4.23	0.03	-6.8	4.88	0.17	191.0	10.63	0.00	10.2	13.48	0.45
15	230	4.5	3.93	0.25	15.2	5.99	0.01	170.0	10.91	0.00	11.0	13.84	0.43
16	674	9.0	2.59	0.00	-2.4	3.14	0.45	215.0	6.67	0.00	2.4	7.94	0.76
SDG&E													
7	2,283	6.0	1.11	0.00	0.9	1.49	0.53	176.0	2.93	0.00	3.8	3.68	0.30
10	1,228	10.0	1.46	0.00	-1.2	1.92	0.53	168.0	3.73	0.00	5.5	4.74	0.25

Table 8-10. Gas normalized annual heating load DID model

Climate Zone	N	DID Intercept			DID slope			Baseline Intercept			Baseline slope		
		Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value	Estimate	std. error	p-value
PG&E													
2	252	-9.7	4.45	0.03	11.7	6.15	0.06	319.0	13.92	0.00	-13.2	16.45	0.42
3	1,319	-5.7	2.19	0.01	10.1	2.98	0.00	277.0	6.76	0.00	-1.3	8.00	0.87
4	1,268	10.2	2.07	0.00	7.6	2.73	0.01	266.0	6.73	0.00	-4.4	7.85	0.58
11	373	-14.3	3.29	0.00	-1.0	4.18	0.81	277.0	10.23	0.00	9.3	12.33	0.45
12	1,718	-10.1	1.78	0.00	6.5	2.34	0.01	297.0	6.18	0.00	-1.3	7.17	0.85
13	287	-16.5	3.91	0.00	6.6	5.06	0.20	265.0	12.65	0.00	-2.9	14.92	0.84
SCG													
5	88	12.2	7.75	0.12	-5.2	9.71	0.59	202.0	15.98	0.00	14.4	19.46	0.46
6	931	-15.5	2.17	0.00	3.0	2.91	0.30	225.0	7.33	0.00	-4.4	9.04	0.63
8	1,689	-6.0	1.33	0.00	0.2	1.71	0.91	172.0	4.28	0.00	5.5	5.18	0.29
9	8,767	-12.2	0.83	0.00	-1.5	1.02	0.13	224.0	2.33	0.00	0.8	2.78	0.79
10	1,350	-1.3	1.59	0.43	-1.5	2.05	0.45	184.0	4.22	0.00	5.6	5.23	0.28
13	195	1.8	3.90	0.65	9.9	5.04	0.05	239.0	13.56	0.00	-4.6	16.00	0.78
14	138	-29.8	5.92	0.00	20.1	7.39	0.01	314.0	17.88	0.00	-10.8	21.33	0.61
15	186	2.2	4.21	0.60	-1.2	5.65	0.83	140.0	10.95	0.00	-11.6	14.28	0.42
16	625	3.3	3.12	0.29	2.6	3.72	0.48	247.0	8.86	0.00	-5.6	10.29	0.59
SDG&E													
7	1,564	-8.9	1.45	0.00	5.1	1.93	0.01	162.0	4.27	0.00	2.4	5.25	0.64
10	873	-12.4	2.11	0.00	4.0	2.70	0.14	175.0	5.68	0.00	-2.6	7.01	0.72

8.8 Appendix H: Total electric and gas savings by PA and climate zone

Total claimed and evaluated savings, and gross realization rates by PA and climate zone, which are the basis of totals at the PA level, are presented in this section. Table 8-11 and Table 8-12 present electric and gas, respectively, savings by PA and climate zone.

Table 8-11. Total electric savings by PA and climate zone

Program Administrator	Climate Zone	Program participants	Total Gross Claimed Savings (kWh)	Total Gross Evaluated Savings (kWh)	Gross Realization Rate
PG&E	1	54	1,404	1,404	100%
	2	1,250	181,524	53,921	30%
	3	5,186	510,944	-76,130	-15%
	4	4,767	514,066	258,476	50%
	5	255	20,663	-1,619	-8%
	11	3,026	850,803	588,535	69%
	12	13,374	2,644,173	1,088,771	41%
	13	7,531	2,842,860	1,254,171	44%
	16	79	16,347	23,731	145%
SCE	6	7,568	724,166	564,398	78%
	8	12,285	1,648,569	247,890	15%
	9	9,189	1,974,815	511,028	26%
	10	36,557	6,640,233	2,662,790	40%
	13	1,406	497,506	391,740	79%
	14	2,587	854,056	531,977	62%
	15	5,935	4,797,385	987,535	21%
	16	1,395	303,578	230,032	76%
SCG	4	174	19,092	5,533	29%
	5	416	34,248	-938	-3%
	6	9,610	914,570	534,246	58%
	7	28	3,388	125	4%
	8	10,262	1,348,027	230,272	17%
	9	10,794	2,344,259	540,197	23%
	10	25,810	4,274,584	1,268,765	30%
	13	500	192,163	126,115	66%
	14	1,550	516,208	284,351	55%
	15	3,442	2,992,004	584,916	20%
	16	2,971	643,136	403,083	63%
SDG&E	6	854	97,356	-12,583	-13%
	7	4,797	634,564	-93,707	-15%
	8	308	46,508	30,661	66%
	10	5,947	2,257,167	482,564	21%
	14	91	30,042	18,713	62%
	15	17	7,823	2,829	36%

Table 8-12. Total gas savings by PA and climate zone

Program Administrator	Climate Zone	Program participants	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate
PG&E	1	54	2,646	2,646	100%
	2	1,250	32,302	14,181	44%
	3	5,186	135,875	44,764	33%
	4	4,767	91,530	20,306	22%
	5	255	4,179	-572	-14%
	11	3,026	63,375	-18,718	-30%
	12	13,374	287,812	202,557	70%
	13	7,531	120,790	7,655	6%
	14	21	519	692	133%
	16	79	4,184	423	10%
SCE	6	7,568	66,901	38,593	58%
	8	12,285	84,672	-18,797	-22%
	9	9,189	92,630	1,604	2%
	10	36,557	400,064	2,736	1%
	13	1,406	25,867	12,585	49%

Program Administrator	Climate Zone	Program participants	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate
	14	2,587	55,658	85,201	153%
	15	5,935	36,418	-63,520	-174%
	16	1,395	71,321	7,464	10%
SCG	4	174	3,088	-5,890	-191%
	5	432	7,287	-968	-13%
	6	11,707	105,531	59,700	57%
	7	28	280	66	24%
	8	14,202	98,967	-21,730	-22%
	9	32,886	407,555	5,739	1%
	10	29,886	315,647	2,237	1%
	13	782	12,745	7,000	55%
	14	1,936	37,549	63,761	170%
	15	3,894	22,511	-41,676	-185%
	16	4,569	256,596	24,445	10%
SDG&E	7	4,397	47,320	10,436	22%
	10	5,058	112,180	15,757	14%
	14	38	767	1,251	163%
	15	3	15	-32	-217%

8.9 Appendix I: Electric and gas savings per household by PA and climate zone

Final estimates of electric and gas savings by climate zone and PA are presented in Table 8-13. The table also provides savings expected per unit of installed smart thermostats in each climate zone. The expected savings presented are averages of the unit kWh (first baseline) and unit therms (first baseline) values provided in the tracking data.

Table 8-13. Final estimated and expected electric and gas savings per household by PA and climate zone, PY 2018

Program Administrator	Climate Zone	Final Estimated Electric Savings (kWh)	Expected Electric Savings (kWh)	Final Estimated Gas Savings (therms)	Expected Gas Savings (therms)
PG&E	2	43.1	145.1	11.3	25.8
	3	-14.7	98.4	8.6	26.2
	4	54.2	107.7	4.3	19.2
	5	-6.3	81.0	-2.2	16.4
	11	194.5	280.4	-6.2	20.9
	12	81.4	197.1	15.1	21.5
	13	166.5	376.0	1.0	16.0
	14			32.9	24.7
	16	300.4	206.9	5.4	53.0
SCE	6	74.6	95.5	5.1	8.8
	8	20.2	131.8	-1.5	6.8
	9	55.6	214.7	0.2	10.1
	10	72.8	173.5	0.1	10.5
	13	278.6	350.4	9.0	18.2
	14	205.6	321.2	32.9	20.8
	15	166.4	796.5	-10.7	6.0
	16	164.9	214.6	5.4	50.3
SCG	4	31.8	109.7	-33.9	17.7
	5	-2.3	79.3	-2.2	16.9
	6	55.6	78.0	5.1	9.0
	7	4.5	121.0	2.4	10.0
	8	22.4	94.5	-1.5	6.9
	9	50.0	70.9	0.2	11.3
	10	49.2	142.8	0.1	10.5
	13	252.2	245.2	9.0	16.3
	14	183.5	266.4	32.9	19.4
	15	169.9	768.4	-10.7	5.8
	16	135.7	140.8	5.4	54.0
SDG&E	6	-14.7	99.1		
	7	-19.5	94.3	2.4	7.1
	8	99.5	133.3		
	10	81.1	210.8	3.1	6.3
	14	205.6	291.7	32.9	7.4
	15	166.4	411.7	-10.7	0.8

Some PAs' climate zones did not have participants with sufficient data to estimate savings per household and required the use of estimates from the same climate zone of another PA to evaluate the claimed savings. The following is a list of savings claims of one PA in a particular climate zone evaluated using savings estimates per household from another PA in the same climate zone:

- PG&E's gas savings claims for climate zones 5, 14 and 16 were evaluated using SCG's savings estimates per household in these climate zones
- SDG&E's gas savings claims for climate zones 14 and 15 were evaluated using SCG's savings estimates per household in these climate zones

- SCG's gas savings claims for climate zone 7 were evaluated using SDG&E's savings estimates per household in these climate zones
- SDG&E's electric savings claims for climate zones 14 and 15 were evaluated using SCE savings estimates per household in these climate zones
- SCG's electric savings claims in climate zone 4 were evaluated using PG&E's savings estimates per household in these climate zones
- SCG's electric savings claims in climate zone 7 were evaluated using SDG&E savings estimates per household in these climate zones

8.10 Appendix J: NTG survey scoring

For the smart thermostat evaluation, DNV GL used similar NTG scoring methods similar to those used for other residential measures. DNV GL's approach focuses on assessing 3 dimensions of free-ridership: timing, quantity, and efficiency. Taken together, these dimensions allow one to estimate the net energy (kWh) attributable to the measure, because that energy is a factor of the number of measures installed (quantity), the efficiency of the measures (efficiency), and the duration that the measures are installed (timing).

Timing and efficiency are directly applicable to all smart thermostat program participants. The applicability of the quantity dimension varied by the type of survey respondent. The various PA-delivered programs that provided smart thermostats to residential customers gave rebates for one smart thermostat installation per household. Thus, participants could only receive a single smart thermostat and the quantity dimension is not applicable. However, survey respondents who are multifamily property managers[34] could be responsible for multiple homes and could have decided to install the thermostats in more or fewer units. Thus, the quantity dimension is applicable to these survey respondents.

The evaluation also conducted surveys of installation contractors to gather the perspective of another market actor. These surveys included *only* the quantity question. Table 8-14 shows the free-ridership scoring algorithm.

[34] All of the multifamily property managers and contractors participated in programs that used direct install delivery channels. Many of the single-family home residents participated in programs with more traditional, downstream rebate mechanisms.

Table 8-14. Free-ridership elements

Survey Respondents	Free-ridership Dimension	Question Wording	Answer	Free-ridership Score
Participants (occupants) Property managers	Timing – (FR_t)	If the program didn't offer a rebate for this/these smart thermostat(s) in 2018, when would you have purchased it/the smart thermostats…?	At the same time or sooner	1
			1 to 24 months later	(24 - # of months)/24
			More than 24 months later	0
			Never	0
			Don't know	Average of non-Don't know answers
Participants (occupants) Property managers	Efficiency (FR_e)	Smart thermostats come in a variety of models, there are BASIC models that cost about $150-$200 dollars (e.g., Nest E and Ecobee 3 lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest 3rd gen and Ecobee 4). If the program didn't offer a smart thermostat rebate/the smart thermostats in 2018, which model would you have likely purchased?	Would have purchased the BASIC model smart thermostat(s)	1
			Would have purchased the UPGRADED model smart thermostat(s)	1
			Would have purchased standard programmable thermostat(s); (e.g., without smart capabilities)	0
			Would NOT have purchased any thermostat(s)	0
Property Managers	Quantity (FR_q) Property Manager survey	In the absence of the program, how many smart thermostats would you have purchased and installed at this property?	The same number or more	1
			Fewer	(#installed - #fewer)/ (#installed)
			None	0
			Don't know	Average of non-Don't know answers
Contractors	Quantity (FR_q) Contractor survey	In 2018, you installed a total of X smart thermostats through PA programs. If the programs had not been available, approximately what % of those installs would you still have provided in 2018?	Open-end (0-100%)	Equal to recorded response

Using these metrics in combination allowed DNV GL to fully assess the amount of savings that could be attributed to measures that participants would have installed absent program support. DNV GL assigned each respondent a score for each free-ridership metric based on their survey responses and combined those scores into an overall free-ridership score using the algorithms in Equations 1 through 3.

Equation 1: Free-ridership Scoring Algorithm for participants based on the occupant survey

$$\textit{Free-ridership} = FR_t * FR_e$$

Equation 2: Free-ridership Scoring Algorithm based on the property manager survey

$$\textit{Free-ridership} = FR_t * FR_e * FR_q$$

Equation 3: Free-ridership Scoring Algorithm based on the contractor survey

$$\textit{Free-ridership} = FR_q$$

Program attribution or net-to-gross ratios (NTGRs) are simply the complement of free-ridership and is estimated as: *NTGR = 1- Free-ridership.*

Results from the free-ridership analysis based on the participant (occupants), property manager, and contractor surveys are summarized in Section 4.2.1. Program level NTGRs derived from participant and property manager surveys are weighted by claims to compute PA level program attribution estimates which are then applied to gross savings to arrive at net savings. Contractor free-ridership estimates represent a verification check of the NTGRs derived from the property manager surveys.

8.11 Appendix K: Sample weights

DNV GL presents summaries of the sample weights developed for the participant and non-participant surveys in this section.

Participant survey – sample weights. The team applied sample weights, in order to balance the participant survey sample to the population proportions by each PA, fuel, climate zone category, and consumption level combinations. No trimming of weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.5, 1.8, and 3.7 respectively (Table 8-15). Minimum cell size to which weights were applied was 32. This indicates a balanced survey sample requiring minor corrections for over and under representation thus reducing the design effect on the data and any potential inflation of standard errors for estimated statistics.

Table 8-15. Participant survey sample weights

PA	fuel	Climate zone category	Consumption level	Sample frame - Frequency	Sample frame - percent	Survey sample – frequency	Survey sample - percent	Proportional sample weight
PGE	DUAL	1	0	3107	4%	728	7%	0.59
PGE	DUAL	1	1	2337	3%	538	5%	0.60
PGE	DUAL	1	2	1314	2%	307	3%	0.59
PGE	DUAL	4	0	1806	2%	410	4%	0.60
PGE	DUAL	4	1	2049	3%	407	4%	0.69
PGE	DUAL	4	2	2802	4%	473	5%	0.81
PGE	ELEC	1	0	327	0%	73	1%	0.61
PGE	ELEC	1	1	203	0%	58	1%	0.48
PGE	ELEC	1	2	169	0%	37	0%	0.63
PGE	ELEC	4	0	332	0%	56	1%	0.81
PGE	ELEC	4	2	472	1%	90	1%	0.72
PGE	GAS	1	0	251	0%	52	1%	0.66
PGE	GAS	4	0	1139	2%	240	2%	0.65
SCE	ELEC	2	0	1782	2%	340	3%	0.72
SCE	ELEC	2	1	1087	1%	186	2%	0.80
SCE	ELEC	2	2	797	1%	135	1%	0.81
SCE	ELEC	3	0	1810	2%	262	3%	0.95
SCE	ELEC	3	1	2383	3%	243	2%	1.34
SCE	ELEC	3	2	2334	3%	185	2%	1.73
SCE	ELEC	5	0	380	1%	72	1%	0.72
SCE	ELEC	5	1	459	1%	47	0%	1.34
SCE	ELEC	5	2	797	1%	62	1%	1.76
SCG	GAS	1	0	531	1%	77	1%	0.95
SCG	GAS	1	1	650	1%	78	1%	1.14
SCG	GAS	1	2	764	1%	72	1%	1.46
SCG	GAS	2	0	25791	35%	2507	25%	1.41
SCG	GAS	3	0	2212	3%	256	3%	1.18
SCG	GAS	3	1	3379	5%	379	4%	1.22
SCG	GAS	3	2	1241	2%	96	1%	1.77
SDGE	DUAL	2	0	1319	2%	211	2%	0.86
SDGE	DUAL	2	1	1485	2%	242	2%	0.84
SDGE	DUAL	2	2	1242	2%	174	2%	0.98
SDGE	DUAL	3	0	767	1%	117	1%	0.90
SDGE	DUAL	3	1	1024	1%	148	1%	0.95
SDGE	DUAL	3	2	1099	1%	151	1%	1.00
SDGE	ELEC	2	0	923	1%	158	2%	0.80
SDGE	ELEC	2	1	656	1%	94	1%	0.96
SDGE	ELEC	2	2	725	1%	96	1%	1.04
SDGE	ELEC	3	0	407	1%	59	1%	0.95
SDGE	ELEC	3	1	201	0%	32	0%	0.86
SDGE	ELEC	3	2	296	0%	33	0%	1.23

PA	fuel	Climate zone category	Consumption level	Sample frame - Frequency	Sample frame - percent	Survey sample – frequency	Survey sample - percent	Proportional sample weight
SDGE	GAS	2	0	600	1%	75	1%	1.10
SDGE	GAS	3	0	574	1%	95	1%	0.83

Non-participant survey - sample weights. The team applied sample weights, in order to balance the non-participant survey sample to the population proportions by each PA, fuel, climate zone category, and consumption-level combinations. No trimming of weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.7, 1.9, and 2.8 respectively (Table 8-16). This indicates a balanced survey sample requiring minor corrections for over and under representation thus reducing the design effect on the data and any potential inflation of standard errors for estimated statistics.

Table 8-16. Non-participant survey sample weights

PA	fuel	Climate zone category	Consumption level	Sample frame - Frequency	Sample frame - percent	Survey sample - frequency	Survey sample - percent	Proportional sample weight
PGE	DUAL	1	0	1071	4%	125	5%	0.83
PGE	DUAL	1	1	1070	4%	134	6%	0.77
PGE	DUAL	1	2	628	3%	72	3%	0.85
PGE	DUAL	4	0	324	1%	35	1%	0.90
PGE	DUAL	4	1	410	2%	49	2%	0.81
PGE	DUAL	4	2	752	3%	83	3%	0.88
PGE	GAS	4	0	401	2%	44	2%	0.88
SCE	ELEC	2	0	640	3%	94	4%	0.66
SCE	ELEC	2	1	517	2%	73	3%	0.69
SCE	ELEC	2	2	428	2%	58	2%	0.72
SCE	ELEC	3	0	26	0%	3	0%	0.84
SCE	ELEC	3	1	458	2%	58	2%	0.77
SCE	ELEC	3	2	393	2%	38	2%	1.00
SCG	GAS	2	0	3690	15%	342	14%	1.05
SCG	GAS	2	1	3919	16%	368	15%	1.03
SCG	GAS	2	2	4252	17%	325	14%	1.27
SCG	GAS	3	0	520	2%	43	2%	1.17
SCG	GAS	3	1	629	3%	53	2%	1.15
SCG	GAS	3	2	482	2%	25	1%	1.87
SDGE	DUAL	2	0	753	3%	66	3%	1.11
SDGE	DUAL	2	1	776	3%	69	3%	1.09
SDGE	DUAL	2	2	610	2%	53	2%	1.12
SDGE	DUAL	3	0	317	1%	31	1%	0.99
SDGE	DUAL	3	1	341	1%	43	2%	0.77
SDGE	DUAL	3	2	392	2%	37	2%	1.03
SDGE	ELEC	2	0	371	1%	27	1%	1.33
SDGE	ELEC	2	1	265	1%	33	1%	0.78
SDGE	ELEC	2	2	377	2%	26	1%	1.41

8.12 Appendix L: Surveys

8.12.1 Occupant surveys – Program participants and Non-participants

8.12.1.1 Program participant survey

This section presents the email invite issued to participants (customers will see the following):

From: "Smart Thermostat Evaluation" support@impact.dnvgl.com

"[UTILITY] Smart Thermostat Evaluation"<support@impact.dnvgl.com>

Subject line: Tell us about your experience with your [utility] sponsored Smart Thermostat

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Dear [Utility] Customer,

Can you be one of the respondents who will help us meet our survey completion goals today? We need customers like you to provide us with feedback regarding your experience with your [Utility] sponsored Smart Thermostat.

As a participant in [Utility]'s program, your opinions are important. [Utility] and the California Public Utilities Commission (CPUC) would like your input and perspectives to understand how to best structure future energy efficiency programs.

We're requesting your participation today in a 6-minute survey. As a thank you for your participation your household will be entered a drawing for a one-hundred-dollar incentive. The information gathered will be used solely for research purposes and your individual responses will be kept completely confidential.

To get started click on this link: [ST]: [https://app.form.com/f/1427683/144a/]

DNV GL is the research provider retained by the CPUC to help administer this survey. If you'd like to validate the legitimacy of this survey, visit the CPUC website for a listing of this and other CPUC approved research efforts underway: http://cpuc.ca.gov/validsurvey

Thank you for helping to improve energy efficiency programs in California.

California Public Utilities Commission
505 Van Ness Ave.
San Francisco, CA 94102

If you would like to unsubscribe from this survey request, please click on this link: [remove]

Online Survey – Introduction Page

Smart Thermostat Survey

Survey Instructions

Hello,

You are invited to take this 6-minute survey and answer some questions about the rebate you received for a smart thermostat. When completing the survey, please provide responses that reflect not just yourself but rather all household members that share the same electric bill. Do your best to answer all questions.

Need Help? DNV GL has been hired to manage this study supported by SCE and the California Public Utilities Commission. DNV GL support representatives can be reached by clicking on this link: support@impact.dnvgl.com

Participant Survey

1. Did you purchase or receive a smart thermostat for your home in 2018?
   Yes
   No > GoTo Q29
   Don't know > GoTo Q29

2. When was the smart thermostat installed in your home?
   2018
   2019
   Has not been installed > GoTo Q29

3. *Show Q3 if (Q2.2018 OR Q2.2019)...*And is this smart thermostat still in place and operational in your home?
   Yes
   No > GoTo Q29

4. Which brand and model did you purchase or receive?
   Nest E (basic model)
   Nest 3rd generation (upgrade model)
   EcoBee 4 (upgrade model)
   EcoBee 3 lite model (basic model)
   Other, e.g., Eco Factor, Emerson, Honeywell, Lux, Radio Thermostat, etc.
   Don't know

5. How much of a rebate did you receive for your new smart thermostat?
   $50
   $75
   My utility sponsored/paid for the new smart thermostat fully. i.e., it was free to me.
   Don't recall

6. To confirm, which utility sponsored your new smart thermostat?
    - Pacific Gas & Electric (PG&E)
    - Southern California Edison (SCE)
    - San Diego Gas & Electric ([UTILITY])
    - [Utility] (SCG)
    - Don't recall

7. How did you first learn about this program?
    - Utility bill insert
    - In-store signage
    - Utility website
    - Word-of-mouth
    - Contractor
    - Don't recall
    - Other, specify:

For these next set of questions, we would like to know how your decision to install the smart thermostat may have changed in the absence of the program.

8. What is the likelihood you would have purchased the same smart thermostat, if the rebate was not available?
    - Very likely
    - Somewhat likely
    - Likely
    - Somewhat unlikely
    - Very unlikely

9. If the program didn't offer a rebate for this smart thermostat in 2018, when would you have purchased it…?
    - At the same time or sooner
    - 1 to 24 months later
    - More than 24 months later
    - Never
    - Don't know

10. Please specify the number of months:

Smart thermostats come in a variety of models, there are BASIC models that cost about $150-$200 dollars (e.g., Nest E and Ecobee 3 lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest 3rd gen and Ecobee 4).

11. If the program didn't offer a smart thermostat rebate in 2018, which model would you have likely purchased?
    - Would have purchased the BASIC model smart thermostat
    - Would have purchased the UPGRADED model smart thermostat
    - Would have purchased a standard programmable thermostat (e.g., without smart capabilities)
    - Would NOT have purchased a thermostat at all

12. How many thermostats, of all types, are installed in your home?
    - 1
    - 2
    - 3
    - 4 or more

13. Have you purchased an additional smart thermostat as a result of your experience with the one you for which you received the rebate?
    - Yes
    - No

14. If yes, how many?
    Specify:

15. Approximately when did you install this/these additional thermostat(s)? Please specify the month and year.

January	June	November
February	July	December
March	August	2018
April	September	2019
May	October	

16. Did you get a rebate from [Q2] for this/these additional thermostat(s)?
    Yes
    No

Your Previous Thermostat Use

17. What type of thermostat did your household use previously?
    Non-programmable thermostat that can be adjusted with an on/off set by hand
    Programmable thermostat that can be set to different temperatures for different times
    Smart thermostat, e.g., Nest, Lyric, Sensi or Ecobee
    No thermostat

18. What type of thermostat(s) did these dwelling units previously use?
    Smart thermostat, Nest, Lyric, Sensi or Ecobee
    Programmable thermostat that can be set to different temperatures for different times *GoTo Q19>*
    Non-programmable thermostat that can be adjusted with an on/off set by hand *GoTo Q19>*

19. How did you use your previous thermostat? Select all that apply.
    Set a temperature and leave it alone (exclusive)
    Turn the thermostat down or up at night
    Turn the thermostat off at night
    Turn the thermostat off when home is unoccupied
    None of these
    Don't recall

20. A smart thermostat can learn energy consumption habits of users through automation. Please select the response choice that best describes how you use your new smart thermostat:
    I use factory default settings
    I have provided some setting preferences and minimal programming of my thermostat
    I programmed my thermostat settings per my schedule and comfort needs
    My smart thermostat is not working/turned on

21. Show Q21 if (Q20.A1 OR Q20.A2 OR Q20.A3) Do you use a mobile app to access your smart thermostat?
    Yes *>GoTo Q22*
    No

22. Which of the following features do you use with smart thermostat mobile app? Select all that apply.
    Remotely lock thermostat use
    Remotely adjust home temperature
    Pre-cool or pre-heat the home to an exact specified time, e.g., use the "Early On" feature
    Use an "Auto Away" feature, where the set point will automatically revert to the set-back temperature if the sensor senses no activity
    Learn more about saving offers from [UTILITY]
    Other, specify:

23. What is the typical thermostat temperature set point you maintain during the winter heating season?

OFF	71–75F
BELOW 55F	OVER 75F
55–60F	I don't have a heating system
61–65F	My heating system isn't currently working
66–70F	Don't know

24. What is the typical thermostat temperature set point you maintain during the summer cooling season?

Off	77–80F
Below 68F	Over 80F
68–69F	I don't have a cooling system
70–73F	My cooling system isn't currently working
74–76F	Don't know

25. Compared to your previous thermostat, would you say your level of comfort with the temperature in the home is less, more, or about the same level of comfort with your new thermostat?
    - Less comfortable
    - More comfortable
    - About the same level of comfort
    - Don’t recall

26. Overall, how satisfied are you with your smart thermostat?
    - Less than satisfied
    - Somewhat unsatisfied
    - Neutral
    - Somewhat satisfied
    - Very satisfied

Technology Use

27. Has your household enrolled in a utility demand response program since installing the smart thermostat?
    - Yes
    - No
    - Don’t know

28. Which of the following products or services do you currently have, are you considering purchasing, or using sometime in the next two years?

    1. Use currently
    2. Would consider use/purchase in the next 2 years
    3. Would NOT consider use/ purchase in the next 2 years

    Product/Program/Service
    - Smart LED light bulbs
    - Smart appliances
    - Home hub or Smart hub
    - Battery storage
    - Time-of-use rates
    - Electronic energy bills or e-bills
    - Automatic bill payments

Household Information

29. Do you own or rent?
    - Own
    - Rent

30. Which of the following building types best describes your home at [ADDRESS]?
    - Single-family detached home (home not attached to another home)
    - Townhouse, duplex, or row house (shares exterior walls with neighboring unit, but not roof or floor)
    - Apartment or condominium (2–4 units)
    - Apartment or condominium (5 or more units)
    - Mobile home
    - Other

31. Approximately how many square feet of living space is there in your home, including bathrooms, foyers and hallways? Exclude garages, basements or unheated porches.
    - Less than 250 SQFT
    - 250–500
    - 501–750
    - 751–1,000
    - 1,001 – 1,250
    - 1,251 – 1,500
    - 1,501 – 2,000
    - 2,001 – 2,500
    - 2,501 – 3,000
    - 3,001 – 4,000
    - 4,001 – 5,000
    - More than 5,000 SQFT
    - Don't know

32. In 2018, were any of the following energy saving upgrades also installed in your home?
    - Water saving aerators
    - Duct test and sealing
    - Evaporative fan motor upgrade
    - Pool pump
    - None of the above
    - Don’t know

33. What is the main fuel type used to heat this home?
    - Natural gas
    - Electricity
    - Propane or other bottled gas
    - Other
    - This home does not use a heating fuel type
    - Don't know

34. What is the main cooling system used to cool your home?
    - Central air conditioner
    - Central heat pump (heats and cools)
    - Mini-split or ductless
    - Evaporative (swamp) cooler
    - Portable window/wall unit
    - I don't have a cooling system
    - Don't know
    - Other, specify

35. Which of the following changes, if any, have you made in your home since 2018? Select all changes that apply or if none please scroll down and select "no changes made".
    - Increased living area/square footage of your home (finished basement to add media room or bedroom, for example)
    - Decreased living area/square footage of your home (converted a bedroom to a storeroom, for example)
    - Using more lighting
    - Using less lighting
    - Using an additional refrigerator
    - Got rid of/recycled/stopped using an additional refrigerator
    - Added a pool
    - Eliminated/stopped using your pool
    - Added electric vehicle charging to the home

No longer charge electric vehicle at the home
Added a spa
Eliminated/stopped using your spa
Household size increased
Household size decreased
Replaced heating or cooling unit
Added heating or cooling unit
No changes

36. Approximately what year was this property built?
    Before 1940
    1940-1969
    1970-1979
    1980-1989
    1990-1999
    2000-2009
    2010-2019
    Don't know

For each of the following age groups, how many people, including yourself, live in this home year-round? Please select one response for each age category.

37. Age category	1. None	2. 1	3. 2	4. 3	5. 4	6. 5	7. 6	8. More than 7
5 and under								
6–18								
19–34								
35–54								
55–64								
65 and over								

38. This information is collected for internal purposes only and remains confidential. Please check the range that best describes your household’s total annual income.

    Less than $10,000
    $10,000 – $19,999
    $20,000 – $24,999
    $25,000 – $49,999
    $50,000 – $74,999
    $75,000 – $99,999
    $100,000 – $149,999
    $150,000 – $174,999
    $175,000 – $199,999
    $200,000 – $249,999
    $250,000 or more
    Prefer not to say

8.12.1.2 Non-participant survey

This section presents the email invite issued to participants (customers will see the following):

From: "Smart Thermostat Evaluation" support@impact.dnvgl.com

Subject line: Subject: Tell us about your thermostat

Dear [Utility] Customer,

[Utility] and the California Public Utilities Commission (CPUC) would like to learn how customers like you use your household's thermostat. Newer technologies like smart thermostats promise customers comfort and control while saving money on your monthly energy bill by being more energy efficient. [Utility] is looking for your input and perspectives on thermostats to inform energy efficiency programs designed to serve customers like you.

Can you be one of the respondents who will help us meet our survey completion goals today?

To get started click on this link: [ST]

We're requesting your participation today in a brief 4-minute survey. As a thank you for your participation your household will be entered a drawing for a one-hundred-dollar incentive. The information gathered will be used solely for research purposes and your individual responses will be kept completely confidential.

DNV GL is the research provider retained by the CPUC to help administer this survey. To check that this is a valid survey, visit this page on the CPUC website: http://cpuc.ca.gov/validsurvey

Thank you for helping to improve energy efficiency programs in California.

California Public Utilities Commission
505 Van Ness Ave.
San Francisco, CA 94102

This email box is not being monitored by [Utility] and is primarily being used for this survey. Any questions about this study may be directed to the study contractor DNV GL at: support@impact.dnvgl.com

If you would like to unsubscribe from this survey request, please click on this link: [remove]

Survey instructions

Hello,

You are invited to take this 4-minute survey and answer some questions about thermostat usage in your home. Do your best to answer all questions.

Need Help?
DNV GL has been hired to manage this study supported by SoCalGas and the California Public Utilities Commission. DNV GL support representatives can be reached by clicking on this link: support@impact.dnvgl.com

Non-Participant Survey

Smart thermostats control a home's heating and/or air conditioning. They perform similar functions as a programmable thermostat (they allow people to control the temperature of their home using a schedule), but smart thermostats have more features, such as sensors and Wi-Fi connectivity, so that settings can be adjusted using smart phones that improve upon the issues with programmable thermostats.

1. Does your home at [Q4] have a smart thermostat installed?
   Yes
   No
   Don't know

2. When was the smart thermostat installed in your home?
   Before 2018
   2018
   2019

3. *Show Q3 if (Q2.2018 OR Q2.2019)...*And is this smart thermostat still in place and operational in your home?
   Yes
   No

4. Which brand and model did you purchase or receive?
   Nest E (basic model)
   Nest 3rd generation (upgrade model)
   EcoBee 4 (upgrade model)
   EcoBee 3 lite model (basic model)
   Other, e.g., Eco Factor, Emerson, Honeywell, Lux, Radio Thermostat, etc.
   Don’t know

5. How many thermostats, of all types, are installed in your home?
   1
   2
   3
   4 or more

Your Previous Thermostat Use

6. You previously indicated that you have a smart thermostat installed in your home. What type of thermostat was replaced by this smart thermostat?
   Non-programmable thermostat that can be adjusted with an on/off set by hand
   Programmable thermostat that can be set to different temperatures for different times
   Smart thermostat, e.g., Nest, Lyric, Sensi or Ecobee
   No thermostat
   Don't know

7. How did you use your previous thermostat? Select all that apply.
   Set a temperature and leave it alone (exclusive)
   Turn the thermostat down or up at night
   Turn the thermostat off at night
   Turn the thermostat off when home is unoccupied
   None of these
   Don't recall

Smart Thermostat User Experience

8. A smart thermostat can learn energy consumption habits of users through automation. Please select the response choice that best describes how you use your new smart thermostat:
    - I use the factory default setting
    - I have provided some setting preferences and minimal programming of my thermostat
    - I programmed my thermostat settings per my schedule and comfort needs
    - My smart thermostat is not working/turned on

9. Do you use a mobile app to access your smart thermostat?
    - Yes
    - No

10. Which of the following features do you use with smart thermostat mobile app? Select all that apply.
    - Remotely lock thermostat use
    - Remotely adjust home temperature
    - Pre-cool or pre-heat the home to an exact specified time, e.g., use the "Early On" feature
    - Use an "Auto Away" feature, where the set point will automatically revert to the set-back temperature if the sensor senses no activity
    - Learn more about saving offers from my utility
    - Other, specify:

11. What is the typical thermostat temperature set point you maintain during the winter heating season?
    - Off
    - Below 55F
    - 55–60F
    - 61–65F
    - 66–70F
    - 71–75F
    - Over 75F
    - I don't have a heating system
    - My heating system isn't currently working
    - Don't know

12. What is the typical thermostat temperature set point you maintain during the summer cooling season?
    - Off
    - Below 68F
    - 68–69F
    - 70–73F
    - 74–76F
    - 77–80F
    - Over 80F
    - I don't have a cooling system
    - My cooling system isn't currently working
    - Don't know

13. Compared to your previous thermostat, would you say your level of comfort with the temperature in the home is less, more, or about the same level of comfort with your new thermostat?
    - Less comfortable
    - More comfortable
    - About the same level of comfort
    - Don't recall

14. Overall, how satisfied are you with your smart thermostat?
    - Less than satisfied
    - Somewhat unsatisfied
    - Neutral
    - Somewhat satisfied
    - Very satisfied

Technology Use

15. Has your household enrolled in a utility demand response program since installing the smart thermostat?
    - Yes
    - No
    - Don’t know

16. Has your household enrolled in a utility demand response program since installing the smart thermostat?
    - Yes
    - No
    - Don’t know

17. Which of the following products or services do you currently have, are you considering purchasing, or using sometime in the next two years?
    1. Use currently
    2. Would consider use/purchase in the next 2 years
    3. Would NOT consider use/ purchase in the next 2 years
    4. Don’t know

    Product/Program/Service
    - Smart LED light bulbs
    - Smart appliances
    - Home hub or Smart hub
    - Battery storage
    - Time-of-use rates
    - Electronic energy bills or e-bills
    - Automatic bill payments

Household Information

18. Are you aware [UTILITY] offers rebates for smart thermostats?
    - Yes
    - No

19. Do you own or rent?
    - Own
    - Rent

20. Which of the following building types best describes your home?
    - Single-family detached home (home not attached to another home)
    - Townhouse, duplex, or row house (shares exterior walls with neighboring unit, but not roof or floor)
    - Apartment or condominium (2–4 units)
    - Apartment or condominium (5 or more units)
    - Mobile home
    - Other

21. Approximately how many square feet of living space is there in your home, including bathrooms, foyers and hallways? Exclude garages, basements or unheated porches.
    - Less than 250 SQFT
    - 250–500
    - 501–750
    - 751–1,000
    - 1,001 – 1,250
    - 1,251 – 1,500
    - 1,501 – 2,000
    - 2,001 – 2,500
    - 2,501 – 3,000
    - 3,001 – 4,000
    - 4,001 – 5,000
    - More than 5,000 SQFT
    - Don't know

22. In 2018, were any of the following energy saving upgrades also installed in your home?
    - Water saving aerators
    - Duct test and sealing
    - Evaporative fan motor upgrade
    - Pool pump
    - None of the above
    - Don’t know

23. What is the main fuel type used to heat this home?

Natural gas
Electricity
Propane or other bottled gas
Other
This home does not use a heating fuel type
Don't know

24. What is the main cooling system used to cool your home?

Central air conditioner
Central heat pump (heats and cools)
Mini-split or ductless
Evaporative (swamp) cooler
Portable window/wall unit
I don't have a cooling system
Don't know
Other, specify

25. Which of the following changes, if any, have been made in made in your home in 2018 or 2019? Select all changes that apply or if none please scroll down and select "no changes made".

Increased living area/square footage of your home (finished basement to add media room or bedroom, for example)
Decreased living area/square footage of your home (converted a bedroom to a storeroom, for example)
Using more lighting
Using less lighting
Using an additional refrigerator
Got rid of/recycled/stopped using an additional refrigerator
Added a pool
Eliminated/stopped using your pool
Added electric vehicle charging to the home
No longer charge electric vehicle at the home
Added a spa
Eliminated/stopped using your spa
Household size increased
Household size decreased
Replaced heating or cooling unit
Added heating or cooling unit
No changes

26. Approximately what year was this property built?

Before 1940
1940-1969
1970-1979
1980-1989
1990-1999
2000-2009
2010-2019
Don't know

27. For each of the following age groups, how many people, including yourself, live in this home year-round? Please select one response for each age category.

Age category	1. None	2. 1	3. 2	4. 3	5. 4	6. 5	7. 6	8. More than 7
5 and under								
6–18								
19–34								
35–54								
55–64								
65 and over								

28. This information is collected for internal purposes only and remains confidential. Please check the range that best describes your household's total annual income.

Less than $10,000
$10,000 – $19,999
$20,000 – $24,999
$25,000 – $49,999
$50,000 – $74,999
$75,000 – $99,999
$100,000 – $149,999
$150,000 – $174,999

$175,000 – $199,999
$200,000 – $249,999
$250,000 or more
Prefer not to say

This concludes our survey. As a thank you for your participation your response will be entered into a drawing for a $100 incentive. If selected as the winning respondent, you will be notified by email. Would you like to be included in the incentive drawing?
Yes, include my response in the drawing
No, exclude my response in the drawing

8.12.2 Property manager survey

This section presents the email invite issued to participants (customers will see the following):

From: "Smart Thermostat Evaluation" support@impact.dnvgl.com

Subject line: Subject: Tell us about your thermostat

Dear [F5],

As a participant in the SCE's Smart Thermostat Rebate Program, your opinions are important. SCE and the California Public Utilities Commission (CPUC) would like your input and perspectives to understand how to best structure future energy efficiency programs.

We're requesting your participation in a 5-minute survey. Please complete this survey by December 31st, 2019. As a thank you for your participation your business will be entered a drawing for a financial incentive. The information gathered will be used solely for research purposes and your individual responses will be kept completely confidential. This survey pertains to multi-family units at: [F3].

To get started click on this link: [ST]

DNV GL is the research provider retained by the CPUC to help administer this survey. If you'd like to validate the legitimacy of this survey, visit the CPUC website for a listing of this and other CPUC approved research efforts underway: https://www.cpuc.ca.gov/validsurvey/

Thank you for helping to improve energy efficiency programs in California.

California Public Utilities Commission
505 Van Ness Ave.
San Francisco, CA 94102

If you would like to unsubscribe from this survey request, please click on this link: [remove]

Survey instructions

Hello,
You are invited to take this 4-minute survey and answer some questions about thermostat usage in your home. Do your best to answer all questions.

Need Help?
DNV GL has been hired to manage this study supported by SoCalGas and the California Public Utilities Commission. DNV GL support representatives can be reached by clicking on this link: support@impact.dnvgl.com

Property Manager Survey

1. Did you receive rebated/free smart thermostats for multi-family units at [Q4]?
    Yes > GoTo Q4
    No > GoTo Q2
    Don't know

2. Who do you suggest we inquire with to learn more about the smart thermostat upgrade? GoTo Q3
    Alternate property manager or building owner
    Installing contractor
    Don't know

3. Please provide an email address so we may inquire with them directly. If you don't know the email address, please provide their name and phone number.
    Contact info: [END]

4. Our records show [Num of] thermostats were sponsored by the program. To your knowledge, how many smart thermostats were installed?
    Quantity:

5. Were all of these smart thermostats sponsored by the utility company?
    Yes
    No

6. [Show if Q5= A1] How many of the [quantity] smart thermostats were sponsored by the utility company?
    Quantity:

7. What type of thermostat was installed? Select all that apply.
    Nest E (basic model)
    Nest 3rd generation (upgrade model)
    EcoBee 4 (upgrade model)
    EcoBee 3 lite model (basic model)
    Other, e.g., Eco Factor, Emerson, Honeywell, Lux, Radio Thermostat, etc.
    Don't know

8. To your knowledge, have any of the program sponsored thermostats been removed, for one or more reasons, since they were installed?
    Yes
    No

9. [Show if Q8 = A1] How many smart thermostats were removed? If you aren't sure of the exact number, your best estimate is fine.
    Quantity:

10. Which of the following best describes the expenses you may have incurred associated with the acquisition of these smart thermostats? Check all that apply.
    The thermostat was FULLY covered by the program
    The thermostat was PARTIALLY covered by the program
    The thermostat and installation service was FULLY covered by the program
    Don't recall/don't know

11. Which of the following best describes the expenses you may have incurred associated with the installation of these smart thermostats? Check all that apply.
    The installation was FULLY covered by the program
    The installation was PARTIALLY covered by the program
    The installation was NOT covered by the program
    Don't recall/don't know

12. Please confirm which utility provided the rebate/sponsored the thermostats for this address [Q4]?
    - Pacific Gas & Electric (PG&E)
    - SoCalGas (SCG)
    - Southern California Edison (SCE)
    - San Diego Gas & Electric (SDG&E)
    - Don't recall

13. How did you first learn about the smart thermostat program?
    - Utility program representative
    - Utility bill insert
    - Utility website
    - Someone within my organization
    - Word-of-mouth
    - Contractor
    - Community based organization
    - Don't recall
    - Other

For these next set of questions, we would like to know how your decision to install the smart thermostats at this property may have changed if there was no rebate program.

14. What is the likelihood you would have purchased the thermostats if the program rebate was not available?
    - Very likely
    - Somewhat likely
    - Likely
    - Somewhat unlikely
    - Very unlikely

15. If the program didn't offer a rebate for these thermostats in 2018, when would you have purchased the smart thermostats in the absence of the program…?
    - At the same time or sooner
    - 1 to 24 months later
    - More than 24 months later
    - Never
    - Don't know

16. [Show if Q15= A2] Please specify the number of months:

17. Smart thermostats come in a variety of models, there are BASIC models that cost about $150-$200 dollars (e.g., Nest E and Ecobee 3 Lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest 3rd gen and Ecobee 4). If the program didn't offer the smart thermostats in 2018, which model would you have likely purchased?
    - Would have purchased the BASIC model smart thermostat(s)
    - Would have purchased the UPGRADED model smart thermostat(s)
    - Would have purchased standard programmable thermostat(s); (e.g., without smart capabilities)
    - Would NOT have purchased any thermostat(s)

18. [Hide if Q17 is equal to A4 (Would not have purchased) or if Q15 = A4 (Never)] In the absence of the program, how many smart thermostats would you have purchased and installed at this property?
    - Quantity:

Previous Thermostat Type

19. What type of thermostats did these dwelling units previously use? Check all that apply.
    - Non-programmable thermostat that can be adjusted with an on/off set by hand
    - Programmable thermostat that can be set to different temperatures for different times
    - Smart thermostat, e.g., Nest, Lyric, Sensi or Ecobee
    - Don't recall/don't know

Smart Thermostat User Experience

20. A smart thermostat can learn energy consumption habits of user through automation. Please select the response choice that best describes how these thermostats were installed:
    - Factory default setting, e.g., eco-mode
    - Provided some setting preferences and minimal programming
    - Programmed the thermostat per a schedule and comfort needs
    - Smart thermostats were not working/turned on
    - Don't know

21. Overall, how satisfied are the tenants with their smart thermostats?
    - Less than satisfied
    - Somewhat unsatisfied
    - Neutral
    - Somewhat satisfied
    - Very satisfied
    - I have not received any tenant feedback

Dwelling Unit Information

22. Which of the following building type best describes this property?
    - Apartment or condominium(s) 2–4 units
    - Apartment or condominium(s) 5 or more units
    - Townhouse, duplex, or row house(s) shares exterior walls with neighboring unit, but not roof or floor
    - Mobile home(s)
    - Single-family detached home(s) home not attached to another home
    - Other

23. Which of the following housing type best describes this property?
    - Most/all units are income qualified
    - Most/all units are senior housing
    - Most/all units are student housing
    - Most/all units are temporary or employee or migrant housing
    - Most/all units are market rate housing
    - Mix of one or more housing types
    - Don't know

24. In 2018, were any of the following energy saving upgrades also installed at this property?
    - Water saving aerators
    - Duct test and sealing
    - Evaporative fan motor upgrade
    - Pool pump
    - None of the above
    - Don’t know

25. What is the main heating system fuel type used to heat these dwelling units?
    - Natural gas
    - Electricity
    - Propane/bottled gas
    - No heating system(s)
    - Other
    - Don't know

26. What is the main cooling system type used to cool these dwelling units?
    - Central air conditioner
    - Heat pump (heats and cools)
    - Mini-split or ductless
    - Central evaporative (swamp) cooler
    - Portable window/wall unit
    - Units do not have cooling systems
    - Don't know
    - Other, specify

27. Approximately what year was this property built? If property is a mobile home park, about when were most/all of the units manufactured? Your best estimate is fine.
    - Before 1940
    - 1940-1969
    - 1970-1979
    - 1980-1989
    - 1990-1999
    - 2000-2009
    - 2010-2019
    - Don't know

8.12.3 Contractor survey

Introduction

Hello, my name is ___ and I'm calling to speak with someone at your company that's familiar with [PA]'s 2018 Residential Smart Thermostat Program. [PA]'s records show your company provides thermostat installation services on behalf of this/these program(s). The reason for my call is our company DNV GL has been hired to perform an evaluation of this program on behalf of the California Public Utilities Commission. The CPUC requests feedback from your company to improve program delivery. We're interested in talking with someone who knows about the sales practices for the incentivized and no cost smart thermostats.

[IF NECESSARY, ADD: "We're not selling anything, this is purely for research purposes to help [PA] improve this/these program(s)]

[IF NECESSARY, ADD: "All your responses will be kept confidential."]

Intro1. Are you familiar with the [program(s)] program?

1	Yes	Goto Intro4.
2	No	Intro1a
98	Don't know	
99	Refused	

a) Is there somebody else with your company who might be familiar with this/these program(s)?

1	Yes	Goto Intro2
2	No	Thank and terminate
98	Don't Know	Thank and terminate
99	Refused	Thank and terminate

b) Is there somebody else with your company who might be familiar with this/these program(s)?

3	Yes	Goto Intro2
4	No	Thank and terminate
98	Don't Know	Thank and terminate
99	Refused	Thank and terminate

Intro2. What is the name and contact information of the person you suggest?

a) Name
b) Title
c) Phone
d) Call back date
e) Call back time

Intro3. And can you give me your name, so I can mention it when I call?

a) Name
b) Title

Thank and terminate.
[Keep following up until the right person is on the phone, then start at beginning]

Intro4. Could you please tell me what your position is at <company>?

1	Record	GOTO FRAMING

Intro5. Which of the following are you familiar with? [CHECK ONE]

1	The sales practices for your whole location	GOTO FRAMING
2	<company>'s sales practices across the entire state of California	GOTO FRAMING
3	Only your own personal (individual) sales	
98	Don't know	
99	Refused	GOTO FRAMING

Intro6. Can you give me the contact information for a person who might be familiar with <company>'s sales practices for your whole location and/or the entire state?

a) Name
b) Title
c) Phone
d) Call back date
e) Call back time

Framing

I'd like to ask a couple questions regarding the program discounted and no cost thermostat measure and what services your company offered prior to joining this program.

Services

Frame 1. Did you offer Smart Thermostats before joining this program?

1	Yes	Frame 2
2	No	
77	Other: (Record)	
98	Don't Know	
99	Refused	

Frame 2. Do you sell Smart Thermostat(s) outside the program to customers who don't get the low/no cost measure? [Select all that apply]

1	Yes	Frame 3
3	No	Ask Frame 2a
77	Other: (Record)	
98	Don't Know	Go to Frame3
99	Refused	Go to Frame3

Frame2a. Why don't you sell Smart Thermostat(s) outside the program?

1	Lack of customer interest	Frame 3
2	Unavailability of rebates to offset the cost	
77	Other: Record	
98	Don't Know	
99	Refused	

Frame 3. If the program stopped offering incentives, would you stop offering Smart Thermostat(s)?

[Check if, "yes, I would stop offering that measure"]

1	Yes	Frame 3a
2	No	Sales practices
77	Other: (Record)	
98	Don't Know	
99	Refused	

Frame 3a. Why would you stop offering the Smart Thermostat(s)?

1	Lack of customer interest	Sales practices
2	Unavailability of rebates to offset the cost	
77	Other: Record	
98	Don't Know	
99	Refused	

Sales Practices

Frame4. Is your company involved in direct program marketing to identify eligible customers to offer the program measures to?

1	Yes	Frame 5
2	No	Frame 6
77	Other: (Record)	
98	Don't know	
99	Refused	

Frame5. Can you describe how your company enlists eligible customers?

1	Record verbatim	Frame6

Frame6a [IF Frame2.A1 = YES] You said earlier that you sell Smart Thermostat(s) outside the program. How, if at all, do you market to customers outside the program?

1	Record verbatim	Attr1
98	Don't know	
99	Refused	

Attribution

Attr1. In 2018 you installed a total of [#] Smart Thermostat(s) through [list of PAs they work with] programs. If the programs had not been available, approximately what % of those installs would you still have provided in 2018?

1	Record %	Attr2a
98	Don't know	Attr3
99	Refused	

a) Why do you say that?

1	Record:	Attr3
98	Don't know	
99	Refused	

Satisfaction & Program Impressions

SAT1. Thinking about your experience with this program what aspects of this program are going well? What suggestions do you have to improve delivery?

1	Record verbatim	
98	Don't know	
99	Refused	

End: Those are all the questions I have for you today. Thank and terminate

8.13 Appendix M: Response to comments matrix

Response ID	Commenter	Comment	Response
1	ClearResult	Due to the increase in post-retrofit load relative to the comparison group, determining smart thermostat savings will crucially depend on an accurate depiction of non-program load changes within the retail thermostat program demographic. Unfortunately, it appears as though the non-participant group was simply too dissimilar to make such a comparison. As noted and discussed in the report, there were obvious differences between the participant and non-participant groups. The survey indicated that program participants lived in newer homes, lived in larger homes, had higher incomes, and more central AC. In addition, the survey indicated more energy-use-increasing actions across most categories for participant households. This combined with the increase in baseload made unequivocally clear that the participant group and the non-participant comparison group were fundamentally different. To account for this, the adjustment made seems to hinge on a proportionality assumption: that percent changes to HVAC loads would be equivalent to percent changes to non-HVAC loads. For example, if the baseload went up 3% for participants versus the comparison group, then it is assumed that the cooling load would have also gone up 3%. No evidence was provided for why this should be true. One can imagine scenarios where the HVAC loads increase less than the baseload (the load growth is coming from EVs or plug in devices) or scenarios where the HVAC loads increase more than the baseload (adding DHPs to previously unconditioned spaces).	It is well-known that in opt-in programs, where subjects self-select into programs, participation or treatment assignment is not random and may be tied to intrinsic characteristics of the subjects in this group. Estimated treatment outcomes will, thus, reflect self-selection bias. In such cases, matching is a method that allows one to select opt-in (treatment) and comparison groups that are balanced along key dimensions. This method does not eliminate the potential for self-selection bias entirely, but it is currently the best we can do to estimate the effect of treatment under the implementation of the programs that delivered smart thermostats. But no quasi-experimental comparison group is perfect. Customers from the same climate zone with the same initial usage level and seasonality will control for a lot of the non-thermostat related changes, but not all. The trend adjustment is an advance over previously available methods. This adjustment can be viewed as a first-order approximation to correcting for the identified differences. It is difficult to define population level scenarios, given the survey data collected, where HVAC load increases more than baseload. The percent increase in baseload provides a proxy that is based on measured energy change based on the data at hand. DNV GL intends to undertake additional analyses based on comparison groups that account for trend in energy use and/or are composed from future participants who also self-select into smart thermostat acquisition. However, the use of matched comparison groups, where matching is based on pre installation data, is the current industry practice in quasi-experimental designs.
2	ClearResult	Because of the dissimilarity between program participants and matched non-participants, we believe that a future participants comparison group is necessary to accurately determine savings. This would ensure a fair comparison to accurately characterize load growth within the retail thermostat participant demographic. This would delay the final answer, though. An alternative to	DNV GL had already drawn up plans to investigate the effect of self-selection by conducting additional analysis using data from future (PY2019) participants; data for these participants was not available in time for the current evaluation but has now become available and will be used as a sensitivity check on the reported results. DNV GL is also planning to explore matching that take trend in energy use

Response ID	Commenter	Comment	Response
		waiting for subsequent participation to develop a future participants group would be to include metrics for the trajectory of energy use 2-3 years pre-retrofit in the matching, rather than a single pre-retrofit year.	into consideration. We plan to explore matching using metrics that account for trend. These include a measures of tenure; technology adoption (as such autobill pay, having an online account with the utility and receiving ebills) that can proxy wealth (having larger homes, higher incomes); rate class (which can flag EV ownership, net metering, TOU); being on CARE/FERA (low income proxies); and receiving energy from community choice aggregators (CCAs) that are primary procurers of renewable energy (proxy for green-orientation). We note that 10%-20% of participants are relatively new movers (having energy use history of only 1 year prior to installing smart thermostats). Thus, while matching on more than one year of pre-installation data is another alternative sample sizes will be more limited with this approach.
3	ClearResult	The report clearly indicates that the thermostat savings were small relative to non-program effects. With that in mind, an accurate assessment of the savings will be almost wholly determined by the nature and magnitude of load growth among program participants. Because of this, we believe that a post-facto adjustment with a flawed comparison group is not the ideal methodology, and that the construction of a sufficiently similar comparison group will be necessary to adequately determine the savings.	See response to comments #1 and #2.
4	Google	Thank you for the opportunity to provide comments on the "Impact Evaluation of Smart Thermostats - Draft" dated March 2, 2020. The evaluation is extensive and detailed and incorporates many data sources and interesting analyses. It's clear that a lot of thought went into the report. Below is a summary of the key issues we see followed by a more detailed set of comments about the study methods and findings as well as some clarifying questions and corrections. While this evaluation uses novel approaches to address self-selection bias, due to the underlying uncertainty associated with the assumptions we recommend completing a follow-on study, designed from the beginning to address bias, before the outputs should be used to develop a new smart thermostat workpaper in California.	DNV GL intends to undertake a follow-on study to address and reduce self-selection bias. This study will still use a quasi-experimental design but will explore matching that control for trend in energy use based on future participants and certain key measures that account for trend. The workpaper development process is separate from the impact evaluation process and will be based on input from Energy Division and other stakeholders. We acknowledge the possibility that changes in workpaper values could wait until follow up analysis is completed.
5	Google	The main takeaway from this evaluation is that there is clear evidence of substantial self-selection bias when	DNV GL agrees that the evaluation finds evidence of possible self-selection bias but does not consider this the main takeaway. The main takeaway is

Response ID	Commenter	Comment	Response
		evaluating smart thermostats by using the common quasi-experimental evaluation design that employs a comparison group matched on prior energy use and geography. This finding is consistent with other studies of smart thermostats. The finding of bias means that the comparison group is not a valid proxy for representing how energy use would have changed for the participants in the absence of the program and calls into question all results based on that comparison group. To their credit, the evaluators investigated for potential bias using customer surveys and billing data analysis. When they found strong evidence of bias, they attempted to reduce it by making ad-hoc adjustments to the results based on some assumptions. The main assumption was that the estimated net changes in baseload usage from the billing analysis represent self-selection bias and that the percent change in baseload can be applied to heating and cooling loads to adjust those for bias as well. These assumptions, although not unreasonable, are ultimately speculative and untestable. Other assumptions and analysis choices could lead to materially different conclusions. The bottom line is that the comparison group is biased in known and unknown ways, and there isn't enough data to adjust with any reasonable level of confidence.	that despite generous attempts to adjust for this possible bias, savings are still well below claimed and workpaper levels. While the adjustments can be characterized as ad hoc, they are based on reasonable assumptions. As evaluators, we must start from the position that savings may not exist. There are, in fact, very few high-quality studies of smart thermostats for the reasons put forward in Google's comments. The recent workpaper efforts found one CA study, with a randomized experimental design, that supported cooling savings only.
6	Google	Even if the proposed bias adjustments were the "right" adjustments, they depend on accurately measuring the component loads (heating, cooling, baseload) across groups which results in high levels of uncertainty due to limitations of billing analysis in accurately extracting load components. This uncertainty is even larger in the smaller evaluation cohorts (PA x climate zone) and shows up as large variations in savings estimates across cohorts that don't make much sense.-- e.g., why do SCE customers in CZ-13 save 279 kWh but PG&E customers in the same climate save 167 kWh? These variations illustrate the large uncertainty in the savings estimates (and suggest pooling across some cohorts).	Component loads do have increased variability when used individually but sum up to a normalized annual consumption estimate that is quite stable and reliable. There may be variability across smaller population climate zones, but, on average, there is no reason to believe that they are downwardly biased. There are a variety of reasons discussed next for why component savings estimates in a climate zone might be different across PAs. Some of the variations in results across PAs within the same climate zone reflect small numbers of participants in one or more of these groupings. While there is variability in usage, savings, usage and savings components across customers, and therefore across groups of customers within a climate zone, the overall results by PA are based on large numbers of customers where the variability is mitigated by aggregation. DNV GL will pool data from PAs across some climate zones to reduce uncertainty in estimates in future evaluations.
7	Google	It's worth noting that the report does not provide any indication of the uncertainties in the savings estimates,	Second stage model results on which these estimates are based are provided in Appendix G. Results include these savings estimates as well as the

Response ID	Commenter	Comment	Response
		even just the internal statistical uncertainties (based on if there is no bias). The true uncertainties are likely to be quite large in comparison to the expected savings, limiting the usefulness of the results in setting policy. It seems clear that future evaluations should be designed to reduce the potential for self-selection bias rather than rely on large post-hoc adjustments.	heating, cooling and overall consumption that comprise denominators of the savings percentages. P-values and standard errors, which can be used to assess precision, are now provided for all estimates. The standard errors of delta NAC provide indications of the variability of the final adjusted savings. To the extent the confidence bounds on these are wide, they indicate that savings are not big enough to be detectable.
8	Google	Although alternate study designs (e.g., using future participants, matching on demographics) should reduce self-selection bias, there is still a need to investigate for remaining bias so that more reliable and actionable savings results can be developed. But stakeholders should also realize that, even with the best study designs, there are real limits to how accurately small heating and cooling savings in the milder climate zones can be measured using billing analysis.	We acknowledge that there is room for further investigation of the potential for bias in smart thermostat estimates. Alternate study designs (e.g., using future participants, matching on demographics) may prove the best available options. As was the case with Opower, the vendors of difficult-to-evaluate measures may need to provide ways to evaluate their measures that are acceptable to evaluators.
9	Google	The evaluation employed the common quasi-experimental billing data analysis design that includes a comparison group matched on geography and prior energy use. The report describes this approach as " robust and reliable " (p.18). But the methodology discussion does not mention that this reliability completely depends on the assumption that the matched comparison group is unbiased -- that the trends in energy use for the comparison group match the trend that would have been found if the participants hadn't participated. Given that the study found that the comparison group is biased, it's surprising to see many instances where the billing analysis results based on this biased group are discussed and compared to expected savings as if they were unbiased.	Appropriate caveats regarding the quasi-experimental design approach will be added to the methodology section. They already have a central role in the findings of the report.
10	Google	The evidence of self-selection bias includes: 1) Survey responses about household changes during the evaluation timeframe that point to the participants being on a trend to increase their energy use vs. the comparison group. For example: a. 4% more participants reported adding an Electric Vehicle b. 2% more participants reported adding refrigerators c. 4% more participants reported an increase in household size	The magnitude of these increases is captured in the baseload increase in consumption that forms the adjustment. The details regarding the adjustment are discussed. These differences all (EVs and refrigerators) or partially (occupants and living space increases) increase baseload. If they are larger in mild climates, then the adjustment based on the baseload differential would be even greater.

Response ID	Commenter	Comment	Response
		d. 2% more participants reported an increase living space These differences can be expected to lead to a substantial increase in energy use over the analysis period that is comparable in magnitude to the savings expected from the smart thermostats -- and quite a bit larger in milder climates. In addition, the survey omitted some other categories that might also provide an identifiable source of bias -- particularly other "tech" products likely to appeal to the same demographic (e.g., smart speakers).	
11	Google	2) Customer demographic surveys found a variety of differences between groups including that participants are more likely to be homeowners and have higher incomes than the matched comparison group. It doesn't appear that the survey asked about the age of the customer, which can be a key indicator of likely trends in energy use over time. A smart thermostat study in Michigan purchased demographic data for their study population and found that participants were much more likely (2x) to be younger households (ages 30-45), much less likely (2.3x) to be senior citizens and were wealthier than their matched comparison group. The younger, wealthier participant households represent growing families that are more likely to have a baby and add end uses (and other tech) -- all of which would lead to increasing energy use over time. An analysis of RECS data found that younger households show increasing energy use with age while the older households show a decrease. The survey results from this California study are consistent with what was found in Michigan.	This is a restatement of evidence put forward in the report to support the adjustments.
12	Google	3) Trends in energy use just prior to installation date (after pre year, during program year) show strong effects for electric but not for gas. The lack of trend for gas is inconsistent with the survey showing growth in household size and home living space. This discrepancy may indicate a limitation of the approach rather than proving a lack of bias for gas use. Unlike electricity where the cooling season is midway through the year, the gas heating season mostly occurs right at the start of the year when any selection effects have yet to occur for	This is a restatement of evidence put forward in the report to support the adjustments.

Response ID	Commenter	Comment	Response
		most participants.	
13	Google	4) Significant net increases in baseload (non-HVAC) electric energy use were found for 19 of the 20 participant cohorts, which is consistent with the biases found from the surveys. Baseload use increased by 112 kWh/yr (2.1%) on average. This observed increase is consistent with but perhaps smaller than might be expected from the survey responses (depending on the timing of the changes in the households). For example, just the 0.04 incremental adoption of EVs for participants can be expected to increase usage by an average of about 100 kWh/yr.	This was the reason for the adjustment, but at the climate zone level. Assumptions regarding home charging of EVs are notoriously difficult. Comments regarding EV consumption showing up in estimates of heating and cooling consumption are addressed in comment #17.
14	Google	The baseload usage increases found in almost every cohort for the electric analysis did not appear consistently in the gas analysis -- 9 of the 17 gas cohorts showed baseload savings instead of increases. This finding is not consistent with the survey results that found an increase in occupants and home size. Baseload gas use is primarily water heating with a small amount for cooking and gas clothes dryers. An increase in occupants should result in an increase in gas baseload. But there are limitations in how accurately weather normalization can separate gas baseload from heating load -- especially in milder coastal climates where some customers may heat any day of the year. So, the estimated changes in baseload may not properly represent the impacts of self-selection.	The challenge of the gas adjustment is discussed in comment #17. The challenges of estimating heating load with site-level models could have a range of effects on estimates. For site-level models to have trouble identifying baseload, households would need to use their heat almost every single day. Since the site-level modeling is done on daily data, it would only take a week of weather warm enough that the heating system did not turn on for a solid baseload estimate to be established. At the same time, it is generally assumed that a certain amount of water heat is picked up in the space heat trend due to higher usage of hot water when it is colder. This would lead to space heating estimates that are upwardly biased and why the baseload does not show the same consistent trend differential as electric.
15	Google	Given the evidence of self-selection bias (i.e., that the comparison group does not properly represent the counterfactual for participants), the evaluators made some post-hoc adjustments. The key assumptions underlying these adjustments are that: 1) the increase in estimated baseload energy use for the participants (net of the comparison group change) is caused by and equal to the impact of self-selection bias on baseload 2) the percent change in baseload use can be used to adjust for self-selection bias in the heating and cooling loads	We agree that these are the necessary assumptions for the adjustments that were made. We also believe the evidence supports both assumptions. To undermine these assumptions, Google's response would need to establish that the baseload differential that we use as the basis of the adjustment is too small on its own (doesn't fully represent the bias in the baseload), and/or that the baseload differential is too small as an adjustment to heating and cooling load (there is more bias in heating and/or cooling than baseload). While we acknowledge some of the considerations offered, we present reasons why others aren't supported by evidence. In total, when it comes to the electric adjustment, the reasonable considerations below (in response to comments #17 to #30) do not combine to either undermine the assumptions or the adjustments themselves.
16	Google	For example, the billing analysis found an average 2.1% net increase in baseload usage which equaled 105 kWh.	We respond to each section in order below.

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		This increase is attributed to self-selection (i.e. not counted against the thermostat savings). A 2.1% increase in cooling load equals 26 kWh on average to adjust for self-selection -- boosting the cooling savings. These assumptions may seem like reasonable guesses, but they are still guesses that may adjust the results by too little or too much. The report justifies these adjustments and suggests they are "generous" because they attribute all the baseload increase to self-selection and then attribute the same percentage change to the heating and cooling loads. But there are several ways in which these adjustments may be too small:	
17	Google	1) Electric Baseload adjustment: If the smart thermostats caused any baseload savings, then the adjustment would be too small. The report claims that the baseload adjustment is generous because the observed baseload increase might be caused by the thermostats because of the smart thermostat customers may run their HVAC fan more often because of the HVAC fan scheduling feature (not commonly found in standard thermostats). This conjecture is not supported with any data. Nest's fan scheduling feature was designed to help customers save energy by reducing the duty cycle of the fan for customers who want to run their HVAC fan in recirculation mode. A significant minority of households use their HVAC fan for continuous recirculation for all or part of the year -- typically to reduce temperature imbalances or filter the air more frequently (see studies in MN and WI). DOE estimates that HVAC fans run an extra 400 hours per year on average due to this behavior. Data from all Nest thermostats installed in California in 2018 found an average of just 105 hours of fan-only runtime in 2019 -- much less than the DOE estimate. This difference can be expected to save an average of 100-200 kWh/yr (more if duct losses are included). These savings would appear in the billing analysis as a combination of baseload and cooling savings because fan-only hours are somewhat seasonal. We can provide more details if needed.	Fan usage is the primary argument that baseload might be too small to be a reasonable proxy for the bias. The argument put forth is that Nest's fan algorithm could save baseload energy. Google's proprietary data regarding "fan-only runtime . . . (of) all Nest thermostats installed in California in 2018 . . . in 2019" (105 hours) is compared to a number described as a "DOE estimate" (400 hours) to imply baseload savings from Nest thermostats. The DOE number that is cited is not actually an estimate of fan run-time. It is provided in a table of assumed values used by the DOE report in the derivation of a separate value. We welcome the additional details offered, but the data presented are insufficient to draw the conclusions stated. Furthermore, in comments on a recent ComEd evaluation (https://s3.amazonaws.com/ilsag/ComEd_Advanced_Thermostat_Evaluation_Research_Report_2018-11-02_Final.pdf) Google states multiple times that smart thermostats have no impact on baseload. In contrast to this, EVs, refrigerators, and lighting are specifically baseload oriented. Additional occupants and square footage will also add to both baseload and heating and cooling load. Argument #3 (Weather Normalization Anomalies (baseload appears as HVAC)), presents the possibility that EVs will also appear as a relative increase in heating or cooling load depending on when they are installed – an artifact of the site-level modeling. This is correct, but only tells part of the story. The scenarios where partial years of EV consumption will specifically contribute to increases in estimated heating and/or cooling relative to baseload are a minority (2 of 16, if one considers all the seasonal permutations of start season and installation season). In an equal number of scenarios, baseload will be increased relative to heating and cool load (EV

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			installed at the start of fall or spring with modeling year ending after that season). In fact, assuming an approximately uniform distribution of annual timeframes across the year and EV installations, we would reasonably expect the effects of this modeling shortcoming to be an approximate wash with respect to increasing or decreasing heating and cooling load relative to baseload. DNV GL also hypothesized that fan usage could increase baseload based on a feature available on smart thermostats that allows regularly scheduled periods of fan use. We know of at least one example where scheduled fan use was calculated to increase consumption by approximately 1000 kWh annual. If this were the case, then the baseload differential would be too big a bias adjustment.
18	Google	2) Electric Heating and Cooling adjustments: The evaluation assumes that the biases hidden within the heating and cooling loads are the same (in percentage terms) as the biases found in baseload. But there are biases that can be expected to affect HVAC loads differently than baseload.	The following three examples are provided to support the idea that the heating and cooling trend differential might be bigger than baseload. That is, that the baseload counterfactual would be too low an estimate to adjust for that trend differential. Each of these examples offers ways that heating or cooling load could be greater, if certain assumptions happen to be true. Importantly, because most of the other survey-related differences have a clear baseload focus, these claims are intended to demonstrate an increase in cooling and heating consumption that would be enough to more than offset the baseload trend increases clearly demonstrated elsewhere.
19	Google	Babies: One potentially major source of bias is the increase in number of occupants found in the survey. It's likely that this increase is due to participants having more babies than the comparison group -- which would be consistent with age differences found in the MI study and general knowledge of the demographics of smart thermostat buyers. Parents learn that babies have poor thermoregulation and are advised to keep temperatures in narrower range. In addition, having a baby often leads to more time with the home being occupied. These changes will certainly increase baseload energy use some but can dramatically increase heating and cooling usage. In milder climates, the percent increases can be huge as households that might let the temperature float during mild weather shift to tighter temperature control. Ideally, customers who have a baby during the analysis period would be matched with comparison group customers who had a baby. But this type of data is not generally available and imbalances between the groups	This argument focuses on babies as part of the relative increase in occupancy. It makes claims regarding the effect of babies on thermostat usage and how babies will lead to an increase in HVAC load. No citations are provided, and the claims are speculative. In general, an increase in occupancy would likely be expected to increase baseload more than heating and cooling load. Incremental increases in baseload (increased use of lighting, refrigerator and other appliances) is unavoidable whereas a wholesale change in HVAC usage would likely require a change in household schedule. Change in schedule related to babies is the only claim that would likely lead to increased heating and cooling load relative to baseload. However, with less than 5% of California households adding a baby in any given year, how much of that 4% differential in occupancy of all ages between participants and comparison is likely to be baby-related?

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		of just a few percent can create significant biases.	
20	Google	House additions: The survey found that the size of living space increased for the participant group. If the added space is an enlarged living room or added bedroom or den, then the baseload usage increase may be smaller than the HVAC load increase.	Google claims some additions will increase heating and cooling load more than baseload. The 2% increase in additions is likely to add relatively low incremental consumption, in general, and increases could be any mix of baseload, heating or cooling load. The one example provided in the survey is finishing a basement, an "addition" that would likely have very limited effects on energy consumption.
21	Google	Internal Gains from Baseloads: Most baseload energy use winds up as internal gains in a home (except for outdoor end uses). These internal gains will add to cooling loads and reduce heating loads. Some basic calculations suggest that a 100-kWh increase in baseload spread evenly throughout the year in an average cooling climate should result in about a 10-kWh increase in cooling kWh. Based on the average loads reported, each 1% increase in indoor baseload can be expected to result in about a 0.4% increase in cooling load.	Google points to the effects of baseload heat gains as increasing cooling load (and decreasing heating load). While the comments mention specific kWh values, we should note that the AC increases due to baseload heat gains are a function several parameters including the amount of cooling, efficiency of the AC, thermodynamic properties of the home, etc. Particularly in mild climates, the conjectured increases are unlikely. Furthermore, many of the baseload increase changes are likely to be outdoor end uses or not in the main part of the house where they would affect thermostat settings. These include EVs, extra refrigerators/freezers and the lighting decreases, which if deemed surplus are more likely to be outside of the core of the house or even outside. Google mentions that, by the same argument, baseload heat gains will lower, not increase, heating load but does not highlight that this would lower the extent to which differential trend is present in heating load.
22	Google	Weather Normalization Anomalies (baseload appears as HVAC): For biases caused by "true" baseload end uses (e.g., EVs) using the baseload bias to represent the heating and cooling bias seems "generous". But the timing of the baseload increase can lead to unexpected results. For example, if a customer added an EV in the post period summer then the weather normalization will mistake much of the load as cooling because usage jumps during the cooling season but only half of the baseload and most of the heating days have already passed. A simulation of this scenario in one climate found that the estimated cooling load would increase by more than 30% if an EV was added in June or July and by 22% if added in August (and the estimated baseload increase would be smaller). Similarly, the estimated heating load would increase dramatically if it were added in November or December. This example illustrates that even adding a true baseload can result in larger increases in the estimated heating and cooling loads	As discussed above in the electric baseload adjustment section, the anomalies associated with an added load such as an EV are well known. There is a well-substantiated argument that across all combinations of thermostat and EV installation dates, the effect will be one of increasing variation in the estimates of all components but not an increase in one component relative to another. One can point to certain combination of the two installations and correctly identify an increase, but across all combinations the effects will be a wash.

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		than in baseload.	
23	Google	Other Changes Known and Unknown: In addition to the scenarios described above, there are many ways that the percent changes in baseload from the bias may differ from the percent change in heating or cooling. Basically, any change in household occupancy patterns can have different impacts on baseload, heating and cooling. It could be people working from home more often, changes in after school activities for children, having a relative move in, and many other scenarios. We are lacking data to assess whether any of these are factors may be present or have a significant impact on the results. Once we know that the comparison group is biased, we are left with guesses and speculation about how to make adjustments. But the "proper" adjustments remain unknown.	This point repeats the general contention that we cannot fully know the effects of the bias. The intent in adjusting the results with baseload differential as a proxy for bias is to assess the possible magnitudes of the underlying bias. The arguments put forth do not successfully undermine the assumptions stated. No argument is made that the baseload differential could be an underestimate of baseload bias. The arguments that overall heating and cooling bias could be greater than the baseload bias is tenuous. At best, they might change the description of the adjustment from “generous” to simply reasonable. The sum total of these arguments does nothing to support a heating or cooling load adjustment 2 or 3 times the magnitude of the baseload adjustment that would be required to return to approximate magnitude in the workpaper.
24	Google	3) Gas Adjustments: The electric load adjustments seemed sensible because the baseload usage increased in a manner consistent with the survey findings of self-selection bias (in 19 of 20 cohorts). But the gas analysis found positive baseload savings for participants in 9 of the 17 cohorts. This finding is not consistent with the survey data showing increasing household size. A closer look in the appendix shows that these gas baseload "savings" had large uncertainties -- the changes were not statistically significant in 14 of the 17 cohorts. So, although the estimates were noisy and inconsistent across cohorts and with the survey data, they were used anyway to adjust the savings. We don't think it makes sense to use the gas baseload changes as self-selection bias adjustments as is. How do net increases in occupants and living space result in a self-selection adjustment that reduces the savings? The inconsistency in applying this approach to the gas analysis illustrates the large uncertainties in the entire complex estimation process.	The assumption with the electric results was that to the extent that the survey and characteristics data supported the possibility of self-selection, it was manifested in the baseload trend differential. The prior comment responses further explain how the baseload trend differential remains the best proxy for an adjustment. On the gas side, the assumption stands that where appropriate, the baseload differential represents the best adjustment. Applying the adjustment in this consistent fashion made very little difference in the gas results at the PA level and maintained consistency with the approach applied to electric.
25	Google	In summary, adjusting results for self-selection bias is ultimately based on untested hypotheses about the nature and influence of the bias and differences in the sources of the bias could mean that the adjustments are too small or too large. This uncertainty in the size and	The arguments presented do not undermine the assumptions underlying the adjustment. The adjustment was designed to address apparent evidence of a differential trend between participant and comparison groups. The comments do not make a convincing argument that the baseload increase in consumption is not a reasonable proxy for trend. Neither do the comments

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		even direction of the adjustments is large compared to expected impacts which makes it hard to have much confidence in the conclusions.	make a convincing argument that heating or cooling trends are likely to be greater than the baseload trend.
26	Google	Uncertainty The evaluation report provides many tables of detailed results but does not provide any estimates of uncertainty in these values. We recognize that the true uncertainties are unknown because the study is based on a biased comparison group. But even standard confidence intervals that ignore this issue would be useful for any party looking to apply those impact estimates. It would be unfortunate if a reported value is used in making policy decisions when even the internal uncertainty indicates that the confidence interval is too wide to be useful.	Please see response to comment #7.
27	Google	There are some p-values reported in the appendix for individual regression coefficients, but they are often oddly truncated to one decimal (what does 0 mean?) and are a crude measure of uncertainty. The (internal) uncertainty in the self-selection adjustments appear to be quite large in many cases especially in smaller cohorts. It would be useful to combine the uncertainty in the point estimates with the uncertainty in the adjustments to report confidence intervals for the cohorts.	Please see response to comment #7.
28	Google	It's also worth looking at how impact estimates and adjustment factors vary across cohorts in ways that look mostly like random noise rather than forming a coherent picture. Do customers in SCE CZ-13 really save almost twice as much on their cooling as PG&E customers in the same climate zone? Do they save 9 times as much on their heating? Pooling across similar climate zones and across PAs may help provide less noisy estimates, although it won't fix any underlying biases from self-selection effects.	There are clear patterns of higher heating and cooling savings in areas of greater heating and cooling consumption. The relatively high level of uncertainty in some CZs is acknowledged. Again, we would expect this to lead to more variable results but not to bias results consistently downward.
29	Google	Recommendations Ultimately, this evaluation makes a valiant attempt to develop unbiased estimates of savings, but the results and adjustments have so much uncertainty (both internal and external) that it would be hard to use them to make sound policy decisions. We strongly agree with	Recommendations are noted.

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		the recommendation to re-analyze the data using a pool of future participants as the comparison group, which should reduce this bias. We also strongly recommend doing a deeper analysis of demographic differences between participants and the potential comparison group (e.g., by purchasing demographic data), potentially using matching on demographics including age, and also focusing more survey questions on changes in the homes over the study period that focus on having babies, changing occupancy patterns (stay at home, work from home) and other potential changes that could impact energy use.	
30	Google	In summary, the "correct" adjustment for a biased comparison group is picking a different comparison group or using a different evaluation design. It isn't devising a set of untestable ad-hoc adjustments that "look ok".	The adjustments are based on sound assumptions. The comments and information presented do not undermine these assumptions nor are alternative arguments proposed that would increase that adjustment to produce savings estimates close to current claimed or workpaper savings. The alternate approach (using subsequent participants) has already been applied to SCG gas data in support of the workpaper and produced an estimate of essentially no gas savings. In the absence of more valid methodologies, the kind of adjustment applied in this analysis may be the only way to develop an estimate of savings in the face of a possible participant trend differential. Nevertheless, DNV GL intends pursue follow up analysis by drawing from future participants to investigate alternative savings estimates of PY2018 (please see response to comments #1 and #2).

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31	Google	Apparent Matching Problems: Although there is a detailed discussion of the complex multi-step matching approach, there is substantial evidence that the matching failed to provide good matches on prior energy use. Based on calculations using the DiD model results in appendix G, we found that the pre-program cooling usage estimates averaged about 5% larger for participants than the matched comparison group. Cooling loads were larger for the participants in 19 of the 20 cohorts. How did this discrepancy happen given the effort in matching on prior energy use? Further discrepancies appear in Appendix K which shows counts of customers broken out by PA, fuel, climate zone category (1-5), and level of energy use (0-4) used for the survey sampling. The tables seem to show that 35% of the participant population was in the SCG Gas CZ category 2, usage category 0 but just 15% of the comparison group was in that category. Even odder, 33% of the comparison group was in SCG Gas climate category 2 and usage levels 1 or 2 but there were no participant cases in those groups. What is the explanation for this?	First, please note that matches were based on 2017 data while the pre-period for participants varied depending on when they installed their smart thermostats. For example, for cohorts that installed smart thermostats in January 2018 their pre-period was 2017 while for those that installed smart thermostats in June 2018, their pre-period was from June 2017 to May 2018. The noted 5% difference in cooling load in the pre-period reflects some of the drift in energy use between participants and matched comparison households beyond the matching period and not matching problems. Second, DNV GL based its matching on actual energy use. The final phase matching, for example, uses total energy consumption and the ratio of summer to winter energy use which provided the best balance among other matching approaches. DNV GL intends to explore matching based on the three load components further in program year 2019, to improve matches on these components. Most importantly, however, is that any pre-period differences that exist between participants and matched comparison households are dealt with the difference-in-difference framework. Since the DID estimator provides the difference in energy use between participants and comparison group households in the pre and post periods, any pre-existing differences are differenced out resulting in an estimate of the change in energy use due to the measure/program. For the same reason, RCT designs also use this modeling framework to account for any pre-existing differences between treatment and control subjects when estimating the impact of treatment, and do not look at post period differences only. The survey sample weights are used to balance who responds to the survey within the participant and comparison groups so there is no over or under representation of respondents along key dimensions (i.e. fuel type, climate zone category, and consumption level within each PA). The dimensions used for weighting are independent of the matching process. There might be some overlap in the dimensions considered for survey sample weighting and the matching, but the matching does not partition the population into consumption categories in the same way that the survey sample does. The objective of the weighting is simply to ensure that the survey samples for the participants and comparison groups are representative of the populations from which they are drawn. In future evaluations, DNV GL will investigate additional balancing that may be required across these two groups.
32	Google	SCG and SCE estimates: The report states that electric savings for SCG are from the SCE analysis and the gas	The electric savings per household tables (Tables 8-4 to Tables 8-7) provide electric savings per household for SCE which are used to estimate electric

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		savings for SCE are from the SCG analysis. But appendix G shows some differences in the savings per participant. Can you explain these?	savings for SCG. The gas savings per household tables (Tables 8-8 to Tables 8-10) provide gas savings per household for SCG which are used to estimate gas savings for SCE. There is mislabeling in the gas tables, which erroneously identify the gas savings to be for SCE instead of SCG. Edits have been made to reflect this.
33	Google	Inclusion of zero heating or cooling: Why does the analysis exclude homes from the heating and/or cooling savings estimates if that load is estimated at zero? How exactly is this implemented? Is it any home where the weather normalization results in a zero estimate (assuming house level models drop heating or cooling if the coefficient is <0) in either pre or post period? For example, did you exclude homes if the estimated cooling load went from 200 kWh to 0?	The analysis excluded homes from heating and cooling models if the weather normalization resulted in zero cooling and heating load estimates in either the pre or post period. The analysis adopted this approach in order to estimate the effect smart thermostats have on heating and cooling savings for those with such estimated loads in both pre and post periods. Results that included households with zero estimated cooling and heating load resulted in models that were not well-determined, and cooling and heating savings estimates per household that were considerably lower.
34	Google	Weather Normalization Screening: Were the house level weather normalization models screened based on model fits? Were outliers removed? What criteria were used?	Yes, these models were screened to remove estimates that had implausible (negative) cooling and heating coefficients. Pre- to post-installation changes in weather normalized energy use that exceed plus or minus 50% are likely due to other changes in the home and not smart thermostat use. DNV GL considered these to be outliers and excluded them from the DID models. Edits were made to include this explanation.
35	Google	Sample Sizes: Are the Ns listed in appendix G a count of participants in the analysis, or do they include the comparison group too? If only participants, are the comparison group Ns always identical?	The listed Ns are for participants. Comparison group Ns are nearly identical in all cases; small differences in participant and comparison group Ns are due to removal of outliers.
36	Google	Claimed Savings Check: We assume that the "claimed savings" used in calculating realization rates is directly from program tracking systems. Have the evaluators looked at whether these savings estimates are consistent with the workpaper in force at the time or with the current workpaper? We have noticed some anomalies in the average savings claimed per participant. For example, Table 8-11 shows claimed savings that average 99 kWh per participant for PG&E CZ-3, but the workpaper shows 84 kWh. To make evaluation results useful, it's important to assess how the evaluated savings compare to estimates from the workpaper (both the old and new workpapers) and not just how they compare to the claimed savings in the tracking system. This will affect the stated realization rates.	Claimed savings are consistent with savings reported in workpaper SCE17HC054.0. For CZ-3, the workpaper shows 102 kWh as the overall savings (84 kWh is cooling only savings) and 99 kWh is the average over the multifamily, mobile home and single family total electric savings.

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37	Google	Savings by Housing Type: The smart thermostat workpaper provides different estimates for savings by housing type and climate zone. It would be useful to provide a break-out by housing type for some of the results, to the extent feasible.	Customer information files that provide housing type for each PA do not provide a complete picture of customer dwelling types. While such information is included, there are many instances where the designation does not match what is reported in program tracking data. DNV GL has attempted to identify and match on housing types in several prior evaluations with mixed success. Future evaluations could attempt to include savings by housing type if reliable information on this variable becomes available.
38	Google	Participation in Other Programs / Measures: Table 3-1 indicates that the evaluation only used tracking data for PY2018. How were customers who participated in other programs removed? Table 3-3 shows that some participants were excluded due to receiving other measures. Was that same criteria applied to the comparison group?	DNV GL did use 2017 tracking data and Table 3-1 will be updated to indicate this. The 2018 tracking provides a list of all claims and measures installed, which were mapped to customer IDs by PA to identify those who installed multiple measures. Participants who installed measures other than smart thermostats in 2018 were removed from the analysis. DNV GL also investigated which of the households that only installed smart thermostats in 2018 had participated in programs in 2017. Tracking data from 2017 indicated that no more than 4% of participant households installed measures in 2017. Not all these households made it into the final analysis dataset. The inclusion of a small percentage of participants with 2017 participation would increase 2018 savings estimates if it had an effect at all. The comparison group was composed of households that did not install any energy efficiency measures in either 2018 or 2017. The tracking data from both 2017 and 2018 were used to remove comparison households that installed measures in either year.
39	Google	NTG: The NTG calculations and the surveys shown in the appendices are not consistent with each other. The NTG scoring (Table 8-14, though referred to as Table 8-31 in the text) does not include several of the related survey questions and does not appear to address potential spillover effects. The surveys themselves also have inconsistencies -- the non-participant survey doesn't appear to ask the same questions related to household changes as the participant survey (Q35 for participants is not the same as Q25 for non-participants)	The timing and efficiency questions shown in Appendix J and in both the participant occupant survey and the property manager survey are consistent. Appendix J's body text refers to 8-14 (body text and caption are aligned/correct). The ATR databases are set up to use a default 5% market effects adder for calculations so the net savings match what is in CEDARS. The calculation is: FY Net Savings = FY Gross Savings * (FY NTG + .05). The non-participant survey included in the appendix now has the full survey which does have the same questions related to household changes as participants. (earlier version seems to have been truncated).
40	Google	Pre and Post and Blackout Periods: Was the billing analysis conducted using CY 2017 as the pre-period and CY 2019 as the post period? Or was there a rolling 12 months pre/post used? The report mentions a one-month blackout period and that extending it didn't make any difference. Was that because it only affected the Dec	The analysis is not based on CY2017 as the pre-period and CY2019 as the post period. It is based on 12 months of pre- and 12 months of post-installation data, and hence involved rolling 12 months pre/post periods. For example, for households that installed smart thermostats in June 2018, their pre period was the 12-month period before installation (June 2017-May 2018), their blackout period was June 2018, and their post period was July

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		2018 installs? If it was rolling periods, can you provide more details on how the results varied with a longer blackout?	2018 - June 2019. The pre, post, and blackout periods followed the same approach for the remaining installation cohorts. Estimated savings were no higher (and were lower for some cohorts) with longer blackout periods such as a blackout period that included the installation month and 2 months after installation.
41	Google	Billing Data: why does the monthly billing data only go through May 2019? Is the entire analysis based on the hourly electric and daily gas data?	We did initial matching on monthly and then on daily data, which required only data from 2017.The analysis for participant and matched households was based on interval data. DNV GL estimated site-level models using daily data aggregated from hourly data and normalized annual consumption values that form the basis of the DID models were based on estimates from these site-level models. The report has been edited to clarify this (section 3.2.1.1).
42	Google	On page 6 the average claimed savings per thermostat are listed as 182 kWh and 13 therms in the text but are listed as 218 kWh and 14 therms in the table below the text. Can you explain this difference? Is it from using different counts of thermostats (all thermostats vs. thermostats claiming savings in that fuel)?	The correct values are the ones reported in the table. The text in the report has been edited.
43	Google	Description of how smart thermostats save energy: On p.5 footnote 1 states " Standard programmable thermostats are the baseline technology, so there is no expectation that the fact that SCTs can be programmed results in savings above this baseline." A major energy savings feature of SCTs is that they are designed to help customers create and maintain an efficient schedule. Field research has shown that about half of all programmable thermostats are not running any schedule. There are additional savings from occupancy detection and other algorithms but creating efficient schedules is a key feature.	Thank you. Please note that this comment relates to footnote 4 that appears in section 2.1. Edits made to acknowledge that not all programmable thermostats are set to run on a schedule.
44	Google	Fan cycling feature: see prior comments about how this feature is expected to save energy compared to the baseline behavior of having just an on/off fan control.	See response to comment # 17.

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45	Google	The report appears to suggest that the ability to remotely control your home HVAC and to have pre-conditioning are features that waste energy. There is no evidence provided to support this contention. a) Pre-conditioning of scheduled set points is designed to allow the customer to employ deeper setbacks without having to compromise on comfort. People who use standard programmable thermostats will typically set their scheduled recovery times to earlier than they need comfort to make sure they don't wake up to a cold house in the winter or come home to a hot house in the summer. Preconditioning optimizes this process to minimize energy use -- rather than having my heat turn up an hour before I wake up every morning (to accommodate the coldest days) preconditioning will turn it just a few minutes early during milder weather -- saving energy. b) The ability to remotely change your thermostats setting also allows customers to employ far deeper setbacks when they are away or on vacation. They can simply turn on the heating or cooling when they are on the way back from the weekend trip rather than setting back by less to avoid returning to a very uncomfortable home that could take hours to reach comfort again.	While it is possible that these features allow for deeper setbacks under different scenarios, we do not have access to evidence that this actually occurs. On the other hand, there are certainly scenarios where these features would increase consumption just as was found to be the case for programmable thermostats.
46	Google	The customer surveys on how people claim to use their smart thermostats could (and should) be compared to actual customer data from Nest. One example showing issues with the self-reports is that 51% of rebate participants and 24% of direct install participants say they use the Auto Away feature of their smart thermostat but actual thermostat data shows that 71% of Nest thermostats installed in California in 2018 have the auto-away feature enabled (as of the start of 2020). It appears that not all survey respondents know all the details of their smart thermostat settings.	Noted. We look forward to using device data were available to add nuance to results. We agree that if the thermostat is contractor installed, customers are less like to be aware of the settings on their thermostats related to this feature.

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47	Google	The customer survey question about NTG asks whether the customer would have bought a basic model smart thermostat or an upgraded model and describing the upgraded model as having additional sensors. The lower and higher cost Nest thermostats have the same sensors and energy savings features. It does not appear that the answer affects the NTG estimates, although it would be good to confirm and to correct this question for the future.	Noted point regarding both having the same sensors. Both the upgraded and basic thermostat responses are scored the same and we confirm that this does not affect the NTG estimates.
48	SDG&E	SDG&E requests that the report explain how the individual climate zone and building type results were weighted and aggregated to produce the program results.	Data from households that installed smart thermostats through rebate programs were used to estimate savings per household. Most homes (90%) in these programs are single family homes and the rest (about 10%) are multifamily homes. Savings per household were estimated by climate zone for each PA and reflect the mix of housing types that exist in the data used to estimate the savings. For each PA, estimates of climate zone level savings per household times the number of participants in the climate zone are used to compute total savings for the climate zone. Total evaluated savings at the PA level are the sum of the climate zone total estimated savings. The report is edited to clarify this.
49	SDG&E	SDG&E requests clarification as to whether HERs program participation was accounted for in the screening for non-participants. SDG&E notes that over 600,000 residential customers in SDG&E service territory participate in the program and would potentially skew the baseline estimate.	DNV GL checked and removed households that participated in all utility energy efficiency programs from the comparison group candidate pool and from the list of those that installed rebated smart thermostats used in the analysis. Due to the vast reach of the HER program, removing HER customers would have reduced significantly the sample available for the smart thermostat analysis. For instance, of the 10,724 SDG&E households used in the smart thermostat analysis, 7,220 were HER participants. What is important for the baseline not to be biased due to HER treatment is that the proportions of HER treatment and control customers among smart thermostat matched comparison and participant groups are the same. In SDG&E's smart thermostat matched comparison group, 14% of households were in HER control groups while 86% were in HER treatment groups. Similarly, in the participant group, 14% of households were in HER control groups while 86% were in HER treatment groups. The proportion of HER treatment and control customers among PG&E's smart thermostat matched comparison and participant groups are similarly balanced. Of the 11,369 PG&E households used in the smart thermostat analysis, 7,236 were HER participants. The proportion of HER control and treatment customers among PG&E's smart thermostat matched comparison group is 23% and 77%

Response ID	Commenter	Comment	Response
			respectively. Similarly, the proportion of HER control and treatment customers among PG&E's smart thermostat participant group is 22% and 78% respectively.
50	PG&E	In Section 4.2.1, the label for Figure 4-1 (and related text just prior to the figure) refers to "Program attribution." As you point out in section 3.1.1, smart thermostats are offered in 18 different programs. Because this smart thermostat evaluation spans multiple programs, some with other measures, would not this estimate of attribution best be characterized as a "Cross-program smart thermostat measure attribution (NTG) and free-ridership" rather than a "Program attribution (NTG) and free-ridership?	Edits made. Thank you.
51	PG&E	Given the large savings variability by climate zone and the number of program-supported installations of smart thermostats, is there any evidence in your survey research that would provide advice for limiting free-ridership in the future?	Survey results indicate that FR is significantly higher in Norther California climate zones 1-5 (55%) compared to climate zones 6-9 and 10 Central-Coastal and Southern California Thermal Belt inland valleys (44% and 46% respectively). Targeting smart thermostat measures in the latter climate zones will enable the program to claim greater share of savings from program interventions.
52	PG&E	Key finding 3 states "the next smart thermostat evaluation should develop methods for identifying trends in pre-installation consumption to include as a matching variable." Our understanding is that your technique for identifying matched comparison households, propensity score matching, is based on pre-consumption trends. Could you please explain further?	DNV GL's matching uses energy consumption data of participant and comparison group households from the matching period (2017). The data used for matching captures energy use at a point in time and not over time. Although energy use between participant and matched comparison households was well-balanced during the matching period, results from the survey and the impact evaluation indicated that the participants were the types of households whose energy use had a different trajectory than their matched counterparts: Their energy use was on the rise post matching but prior to smart thermostat installation, their self-reported information revealed them to be wealthier and to engage in more load building activities, and they had increases in baseload when none is expected given that smart thermostats target HVAC use. See responses to comments #1 and #2 about the limitation of quasi-experimental studies and DNV GL's proposed updates.

Response ID	Commenter	Comment	Response
53	SCE	It is not clear how data from low income customers and those living in multi-family homes have been presented in the report. Did evaluators attempt to disaggregate measure savings from low income customers from non-low-income customers? Provide clarification. If possible, the study should attempt to clearly provide estimates of measure savings and program influence between different demographics particularly including low income and customers living in disadvantaged communities, as well as distinguish between energy savings between single family and multifamily households.	In program year 2018, smart thermostats were delivered through direct install and rebate channels. The rebate channels were open to all customers and had a large proportion of customers who lived in single-family homes; based on the tracking data and interview with program staff, 90% of rebate customers were single family homes while 10% were multifamily homes. Direct install programs delivered smart thermostats to targeted populations in multifamily and mobile homes, and to a certain extent, general residential homes. DNV GL evaluated this first large smart thermostat roll out using data from rebate programs to get a clean read on smart thermostat savings because most households in these programs only installed smart thermostats and nothing else. The direct install programs, which include a larger proportion of lower income customers, offered smart thermostats among a bundle of other measures, all of which affect household energy use jointly requiring complicated statistical decomposition of savings into the various measures installed. Section 3.1.1 of the report details the rationale for this choice. Savings per household from rebate programs were used to evaluate savings from all thermostat installations. Please note that DNV GL intends to estimate savings of smart thermostats offered through direct install programs in program year 2019.
54	SCE	Were energy savings as a function of thermostat connectivity evaluated, e.g., installations with functional vs non-functional Wi-Fi connectivity? Was data available to evaluate persistence of energy savings? Provide clarification. If possible, the report should provide a breakdown of the savings from Wi-Fi and non-Wi-Fi communicating devices.	All smart thermostats offered through the rebate and direct install programs were required to be communicating and Wi-Fi enabled. There was no data to what extent households with smart thermostats did not have a functioning Wi-Fi and, thus, the evaluation could not and did not take that into account.
55	SCE	Were thermostat daily schedules considered as during the evaluation and were they additionally compared with DEER or RASS schedules? Thermostat schedules should be considered, and breakdown by daily schedules per Climate Zones should be reported.	DNV GL did not have access to vendor data that provides such information and did not use this information in the evaluation; DNV GL had discussions with vendors and determined that household specific data about how customers use smart thermostats (including schedules) would not be available for use in the evaluation.
56	SCE	Please clearly state how 'cooling load' and 'heating load' was defined in the report. Is this compressor + fan energy during cooling? With regards to gas load, is this heater energy plus fan energy during heating? Finally, was ventilation fan energy accounted for in the savings? Clarify information in report.	Cooling and heating load are portions of energy consumption estimated from site-level models. The site-level models used in the evaluation produce parameters that indicate the level of energy consumption not correlated with either heating degree days (HDD) or cooling degree days (CDD), and the levels of energy consumption correlated with HDD (heating load) or CDD (cooling load). The portion of energy consumption that is not correlated with weather or is not weather dependent is baseload while the portion of energy consumption correlated with HDD (heating need) is heating load and that correlated with CDD (cooling need) is cooling load. The report has been edited to clarify this definition.

Response ID	Commenter	Comment	Response
57	SCE	Equipment runtime information could further improve disaggregation of load profiles. Consider gathering runtime in future evaluations.	Such device data is only available from vendors. DNV GL held discussions with vendors to determine what is available, but the discussions indicated that either these data are not available/shareable or are only available in aggregated form and not at the household level.
58	SCE	How was dual participation, if any, with Demand Response programs evaluated? Was this part of the survey? If not, why not? If Demand Response participation is not considered, it can potentially be difficult to determine program influence. DR programs by themselves also reduce energy load overall in addition to peak load shifting. Future studies need to estimate savings through Demand Response programs separately.	DNV GL requested data on demand response participation for those that installed smart thermostats and mostly received partial information and could not incorporate the effect of demand response in the evaluation. DNV GL will consider the role such participation plays in smart thermostat savings in program year 2019. The survey indicated that 26% of participants reported enrolling in demand response programs compared to 14% of the subset of the comparison group that had smart thermostats. Given this, the overlap with DR programs would increase savings estimates if it had any effect on the results. Please note that DNV GL's recommendations recognized the DR potential of these devices. DNV GL agrees that studies that focus on the role of smart thermostats in demand response programs will be useful.
59	SCG	1) Lack of Justification for Two-stage Model: The report strongly advocates for the Two-stage Model for estimating changes in energy consumption, stating that the approach is "enshrined" in California and the DOE-sponsored Uniform Methods Project and that it has a "long track record." However, the Uniform Methods Project report does not provide strong justification for the Two-stage Model because it lacks empirical support for the accuracy of the Two-stage Model and the discussion only includes two references to prior literature, both from 25+ years ago. Therefore, this smart thermostat energy savings analysis report should provide further justification for the Two-stage Model, especially as an alternative to a more straightforward Difference-in-Differences (DID) model, which is the standard in academic, peer-reviewed impact evaluation literature.	The two-stage model is essentially a combination of site-level modeling or weather normalization in the first stage and a DID model in the second stage. The two-stage model is a 'straightforward' DID model. It also produces similar results to single stage panel DID models but has the potential to better characterize heating and cooling load because the weather normalization is done at the individual site level.

Response ID	Commenter	Comment	Response
60	SCG	2) Two-stage Model Could Mute True Effect: The lack of justification for the model is especially concerning given that SoCalGas research from Nexant has shown that the Two-stage Model could mute the true effect of the smart thermostat. The Two-stage approach to modeling total pre- and post-treatment consumption does not account for the uncertainty nor the potential lack of fit from the initial, site-level regression models when they are fed into the difference-in-differences model. A high degree of variability in the consumption of a household or a model that is poorly specified for a household are both scenarios that would introduce noise into the DID model and therefore mitigate the true magnitude of the treatment effect. The report should evaluate the fit of the site-level models to gain insight into the size of this potential issue and address it, perhaps by using a more straightforward DID model, at least as a comparison.	DNV GL estimated total energy consumption changes using difference in difference models without weather normalization and found results that were qualitatively similar to those based on NAC (normalized annual consumption). Both models indicate the lack of total energy savings. The two-stage model allows the decomposition of savings into baseload and heating load, and this decomposition made it possible to estimate heating load related savings where they existed. The solution for the uncertainty introduced by weather normalization is to explore ways to fit better weather models. DNV GL will explore further the role that weather normalization plays in estimated savings in program year 2019 evaluation.
61	SCG	3) Noisy Gas Savings Results: Perhaps resulting from the Two-stage Model, the gas savings results are noisy, based on a comparison of results for the same climate zones across utilities. As shown in Table 5-2, the Percent Gas Heating Load Savings are +2.8% for PG&E and -11.7% for SoCalGas in Climate Zone 4 and +2.3% for SDG&E and -0.8% for SoCalGas in Climate Zone 10. The SoCalGas results also show high variance across climate zones, with a range of -11.7% to +6.4%, an extremely wide range of 18.1% as compared to 4% for PG&E and 0.8% for SDG&E.	Results from Nexant and Navigant, using a subsequent participant design that should be more robust to self-selection, found effectively no savings for SCG. Those results were not reported at the climate zone level. These results would have similar variability to prior work if reported at the PA level. Please also see response to comment #6.

Response ID	Commenter	Comment	Response
62	SCG	4) Results with Blackout Period are not Reported: Most smart thermostats do not realize their full potential in terms of savings immediately upon installation. They require time to learn the user's schedule and adjust their algorithms accordingly. Consequently, including this learning period in the post-treatment interval will result in savings estimates that are lower than the true savings once the thermostat reaches its full functionality. In the SoCalGas investigation into this issue, Nexant found that excluding a 30-60-day period following installation increased therm savings estimates by 41% to 73%. However, the report states that the authors saw little change when they attempted this. An elaboration on the methodology and results from this assessment would be useful to include, particularly for gas savings.	DNV GL uses a 30-day blackout period in the analysis. Longer blackout periods, of 90 days, did not produce materially different estimates and, in general, tended to produce lower savings per household. Results from differing blackout periods will be considered and presented in future evaluations. See also response to comment #40. In its July 26, 2019 memo, Nexant estimated gas savings for SCG at <1%. Increases of 41% to 73% on that base are not meaningful.
63	SCG	5) Program Year Definition for Gas: This report provides PY 2018 results for electric and gas. However, the gas savings are going to be noisier when the heating season is based on three months in the early part of the year (Jan-Mar 2018) and two months at the very end of the year (Nov-Dec 2018). Therefore, SoCalGas recommends estimating the results specifically for heating season (Nov-Mar), which will most likely lead to more reliable results.	Heating savings are based on winter months defined as December, January and February. DNV GL used 12 months of pre and 12 months of post installation data in the analysis. As indicated in the report, installations happened throughout 2018. For instance, for those that installed smart thermostats in June 2018 (when most installations happened), their post period covered July 2018 until June 2019. The post winter months for such customers covered the contiguous winter months of December 2018, January 2019 and February 2019. Most participants' post period winter months covered the same three months and the program year definition of the kind noted in the comment is not an issue for gas savings estimates.
64	SCG	6) Removal of Outliers: The report does not discuss removal of outliers in the daily/monthly gas data. SoCalGas recommendations include a brief discussion on how outliers in the usage data were treated.	Please see response to comment #34.
65	SCG	7) Report Omits Increased Savings Opportunities: The report recommendations omit the fact that SoCalGas could potentially increase savings quite a bit by working with Nest to implement "Seasonal Savings" in advance of each winter. This energy savings algorithm can be dispatched to customers using an opt-in RCT design, which could allow SoCalGas to claim savings much more easily.	Noted. Seasonal savings has previously been supported by the PAs on a separate basis than the basic installation of the thermostat. It is our understanding from Google that some of SCG's participants were, in fact, included in "Seasonal Savings" program in the post period of this evaluation. If "Seasonal Savings" is claimed separately from the thermostat itself, this would constitute double counting. If "Seasonal Savings" were going to be included as part of the thermostat savings claim, then it would have to be part of the basic thermostat package.