Impact Evaluation of Residential HVAC Measures

Residential Sector - Program Year 2020

EM&V Group A

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1 EXECUTIVE SUMMARY

1.1 Background

DNV evaluated four residential heating, ventilation, and air conditioning (HVAC) measures[1] installed in program year 2020 (PY2020). These measures, which include smart thermostats, fan motor replacements, fan controls, and duct testing and sealing, improve the operation of the HVAC system and reduce the amount of energy it uses.

Smart thermostats are Wi-Fi-enabled devices that help customers to maintain desired temperature levels by controlling their home's HVAC system from anywhere and optimize the performance of the HVAC system through automatic setbacks based on occupancy sensing capabilities. Fan motor replacement involves installation of high-efficiency brushless fan motors in place of existing permanent central HVAC fan motors. The brushless fan motors consume less electrical energy to move air through the HVAC system reducing electricity consumption during all hours of the system's operation including peak demand periods. A fan motor control delays turning off the fan motor at the end of an air conditioning or heating cycle to increase the HVAC system's effectiveness by extracting the remaining cooling or heating potential. Duct testing and sealing involves testing and sealing residential ductworks by a contractor to reduce leakage losses to specified levels. This reduces leakage losses in residential ductworks to deliver more of the heating or cooling to the occupied space.

In 2020, these four measures were offered by 21 energy efficiency programs delivered by either direct install[2] or rebate channels by six California program administrators (PAs).[3] The programs, which were offered to both electric and gas customers, targeted residential customers in single-family, multifamily, and mobile homes. Statewide, PA programs claimed 58,000 residential HVAC installations in 2020.[4]

1.2 Research objectives

DNV's research objectives in this evaluation were to:

- Estimate the electric and gas savings associated with PY2020 installations of smart thermostats, fan motor replacement, fan motor controls, and duct testing and sealing.
- Determine the extent to which evaluated savings estimates matched claimed savings.
- Estimate the proportion of program installations that would have occurred in the absence of the programs.

DNV also sought to understand program participant characteristics, including dwelling type, location, general demographic background, energy-efficiency program participation, and energy consumption behaviors.

1.3 Study approach

DNV evaluated savings from the residential HVAC installations using energy consumption data analysis and surveys. The two main processes we used to estimate savings were:

- Estimating the energy savings of the measures by comparing energy consumption data for program participants from before and after installation of the device with parallel data for a matched comparison[5] group.

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[1] An energy efficiency measure is an energy-using appliance, equipment, control system, or practice whose implementation results in reduced energy use while maintaining a comparable or higher level of service

[2] Direct install energy efficiency programs are those in which energy saving upgrades are installed for no or low-cost to customers.

[3] The six PAs are Marin Clean Energy (MCE), Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas and Electric Company (SDG&E), and Tri-County Regional Energy Network (3C-REN).

[4] Statewide, PA programs claimed approximately 154,000 residential HVAC installations in PY2019 and 149,000 residential HVAC installations in PY2018

[5] A matched comparison group is a set of non-participants with similar energy consumption profile, fuel type, and location as participants chosen to account for the effect of non-program changes on energy consumption. This enables the estimation of program installed measure savings.

- Conducting surveys to determine the portion of these savings that are due to program intervention, as well as to characterize participants.

Estimate Energy Savings. The majority of rebate program participants were single-family homes receiving smart thermostats with no additional program measures. On the other hand, direct install programs delivered multiple measures to single-family, multifamily, and mobile homes.

- The rebate program evaluation uses consumption data analysis to estimate whole-home savings. Since rebate participants only installed smart thermostats, the whole-home savings is the estimate of smart thermostat savings.
- The direct install program evaluation also uses whole-home consumption data analysis to estimate savings. Since direct install programs typically deliver multiple measures, DNV used a method to allocate whole-home savings to the multiple installed measures using engineering estimates. To the extent practical, DNV also used separate consumption data analysis for direct install homes that received single measures to confirm the allocation of the whole home savings.

COVID-19 implications for the PY2020 Residential HVAC Evaluation. This analysis includes installations and consumption data that occurred during the COVID-19 pandemic, which began in California on March 19, 2020, with the statewide lockdown. The pandemic affected program deployment, has implications for the evaluation, and may have had differential impacts on measure effectiveness. Due to the pandemic, the number of PY2020 installations were lower, at approximately one-third of installations in PY2019 and PY2018.

- In order to have a more robust basis for the evaluation, we augmented the data used in our analysis with participants from the second half of 2019. The additional 2019 participants were not included in any prior evaluation. Thus, both rebate and direct install savings for PY2020 are based on consumption data analysis using installations from mid-2019 through the end of 2020. This approach enables a robust basis for the analysis given that the PAs ran the same programs targeting similar customers in both years.
- The COVID-19 pandemic also has the potential to affect the evaluation in important ways. Billing analysis is designed to use a comparison group to control for non-program-related, exogenous changes that might otherwise be conflated with program impacts. The transition into COVID-19, with periods of full shutdown followed by varying degrees of re-opening, represents far more exogenous change than a billing analysis comparison group is typically expected to address. To complicate matters, segments of the population have been affected differently with varying proportions of people able to work from home. By increasing the variation of customer energy consumption trends, COVID-19 makes the reliance on a comparison group both more essential and riskier. The additional variability of the pandemic period injects a degree of variability into results (potential bias in either direction) that will not necessarily be reflected in precision estimates but may explain anomalous results.
- For the smart thermostat, changes in customer habits due to COVID-19 could undermine the effectiveness of some of the optimization functions of the measure. For example, optimizing setpoints may be more difficult when occupants are home all the time and thus reducing opportunities for setbacks that could help achieve savings.

Program Influence and Customer Characteristics. We surveyed PY2020 program participants[6] for both rebate and direct install programs. In addition to informing program influence and gross[7] savings adjustments, surveys provided information on customer characteristics, energy use behavior, COVID-19 impacts, and demand response program participation. We also

[6] For direct install programs, survey data collection was hampered by lack of reliable information regarding parties responsible for decision-making and lack of contact information for end users for direct install programs.

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

collected information from a sample of non-participants[8]. The sample size for these surveys satisfies overall confidence and precision requirements of 90/10.

1.4 Key findings

1.4.1 Gross and net impacts

Overall, evaluated gross savings were lower and program influence was higher than claimed levels. Table 1-1 provides the number of households with electric service that received residential HVAC measures through direct install or rebate programs, the claimed electric savings (total gross claimed savings), and the achieved savings (total gross evaluated savings). These measures achieved approximately 4.6 GWh of gross electric savings, which is 27% of gross claimed savings (gross realization rate).[9] Total gross savings are further adjusted to reflect the portion of savings that are due to program influence using net-to-gross ratios (NTGR)[10]. Evaluated NTGRs exceed claimed values for all measures and delivery channels except for rebate smart thermostats. Our evaluation indicates that direct install and rebate programs achieved net electric savings of 3.1 GWh statewide.

Table 1-1. Total residential HVAC electric savings, PY2020

Delivery Channel	Program participants	Total Gross Claimed Savings (kWh)	Total Gross Evaluated Savings (kWh)	Gross Realization Rate	Claimed NTGR	Evaluated NTGR	Total Net Evaluated Savings (kWh)
Smart thermostats							
Direct Install	29,991	5,365,793	333,102	6%	66%	80%	267,056
Rebate	25,129	2,876,022	2,045,931	71%	55%	46%	932,175
Measure Total	55,120	8,241,815	2,379,033	29%	62%	50%	1,199,231
Fan motor replacement							
Direct Install	11,601	4,880,184	970,840	20%	66%	89%	863,188
Rebate	1	379	84	22%	55%	89%	74
Measure Total	11,602	4,880,564	970,924	20%	66%	89%	863,263
Fan motor controls							
Measure Total	10,246	3,364,350	444,034	13%	68%	86%	382,554
Duct testing and sealing							
Measure Total	6,219	373,222	766,855	205%	66%	79%	605,489
All Measures							
Grand Total	**83,187**	**16,859,951**	**4,560,846**	**27%**	**N/A**	**N/A**	**3,050,536**

Table 1-2 provides the number of households with gas service that received the measures through a direct install or rebate program, claimed gas savings, and the savings that they achieved. These measures achieved approximately 203,000 therms of gross gas savings, which is 28% of gross claimed savings (gross realization rate). Evaluated NTGR for direct install thermostats and duct sealing are greater than claimed while the NTGR for rebated smart thermostats is lower than claimed at 47% compared to 55%. Our evaluation indicates that direct install and rebate programs caused gas savings of 141,681 therms statewide.

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8 Non-participants are customers from the general residential population who have not participated in any PA programs.

9 Gross realization rate is the ratio of evaluated savings to the original claimed savings, without any adjustments for program influence.

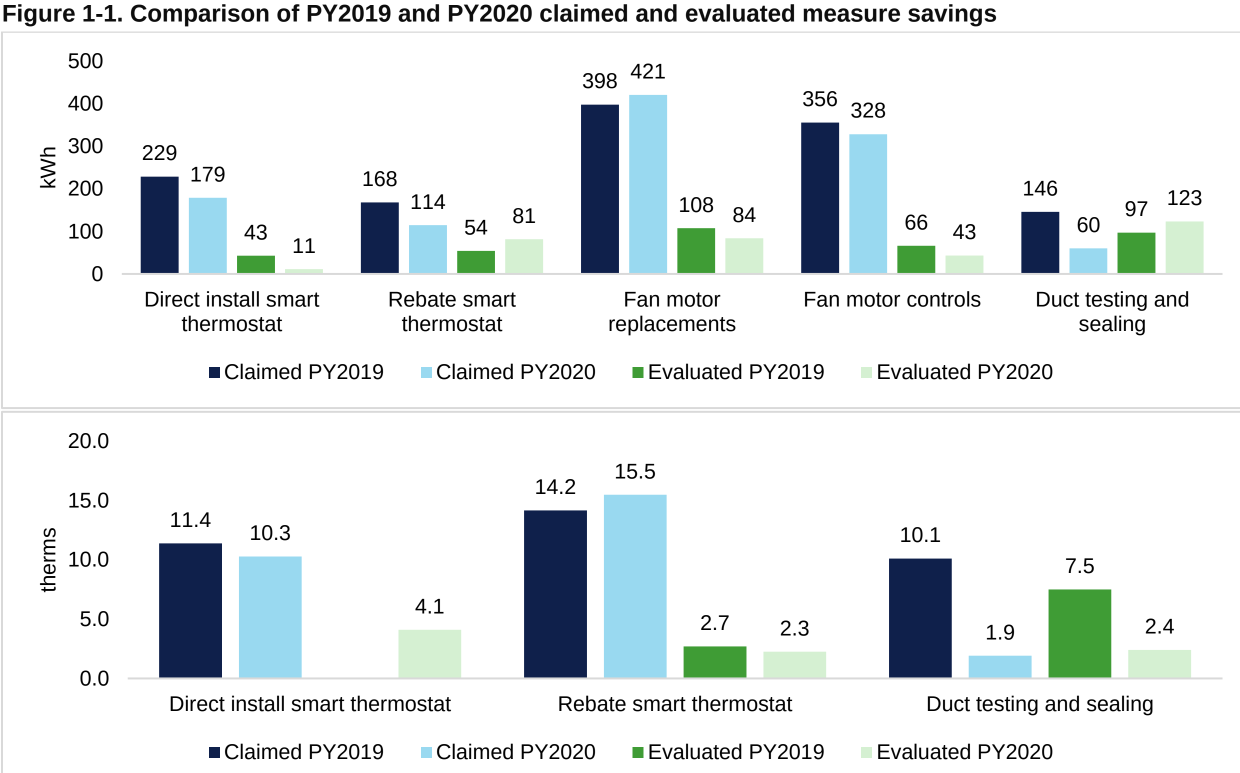
10 Free-ridership is defined as the extent of program participation that would have occurred even in the absence of program incentives. Free-ridership ranges from 0% to 100%, with a with a lower value translating to greater program influence on a customer's decision to participate. The net-to-gross ratio (NTGR) is the complement of free-ridership and measures the amount of savings attributed to program incentives. For example, an 80% NTGR indicates 20% free-ridership. Gross savings are multiplied by the NTGR to arrive at net savings.

Table 1-2. Total residential HVAC gas savings, PY2020

Delivery Channel	Program participants	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate	Claimed NTGR	Evaluated NTGR	Total Net Evaluated Savings (therms)
Smart thermostats							
Direct Install	32,592	334,760	133,472	40%	64%	78%	104,108
Rebate	24,182	374,485	54,557	15%	55%	47%	25,642
Measure Total	56,774	709,245	188,029	27%	59%	69%	129,750
Duct testing and sealing							
Measure Total	6,219	11,901	14,914	125%	66%	80%	11,931
All Measures							
Grand Total	**62,993**	**721,146**	**202,943**	**28%**	**N/A**	**N/A**	**141,681**

Most of the individual measure savings estimates are broadly consistent over time. Figure 1-1 provides claimed and evaluated measure-level savings for rebated thermostats and all direct install program measures for PY2019 and PY2020. For most measures, the savings are of roughly similar magnitude between the two program years and are lower than claimed. For the measures with greater differences year to year, these differences are likely due to a combination of reasons. The mix of climate zones where measures are installed as well as the mix of other measures with which they're installed vary. Changing occupancy patterns and household economic circumstances due to COVID-19 affect the way equipment is operated. These are all physical factors that can affect savings. There is also likely some estimation error, of unknown direction, introduced in PY2020 by differences between participants and their comparison group in COVID-19 effects on the households. Further details are provided in Sections 6.2 and 6.3.2.

Figure 1-1. Comparison of PY2019 and PY2020 claimed and evaluated measure savings



For example, electric savings for direct install smart thermostats are lower in PY2020 than in PY2019 largely because of the absence of electric savings for multifamily participants in PY2020 (Figure 1-2). The number of installations in PY2020 among this segment of the direct install population appear to have been affected by COVID-19 disruptions and the estimated electric consumption change for this segment of participants are not different from statistical noise.[11] This is in contrast to the estimated savings of 56 kWh in PY2019 for direct install smart thermostat installation in multifamily homes.

While we lack visibility into electricity consumption for a large number of SCG customers, the dataset used in the PY2020 consumption analysis is of sufficient size to estimate savings, if they were present. Further, PY2020 installations were concentrated in climate zone 13 which has more cooling and heating needs than PY2019 installations that were largely installed in milder climate zones 6, 8, 9, and 10. Thus, the current results are surprising and counterintuitive. Possible reasons for this outcome are noted above.

Further, unlike PY2019, there are measurable gas savings for direct install participants in single family and multifamily homes in PY2020, resulting in notable differences in gas gross realization rates for this measure.

Figure 1-2. Measure-level electric and gas savings, PY2020 direct install programs

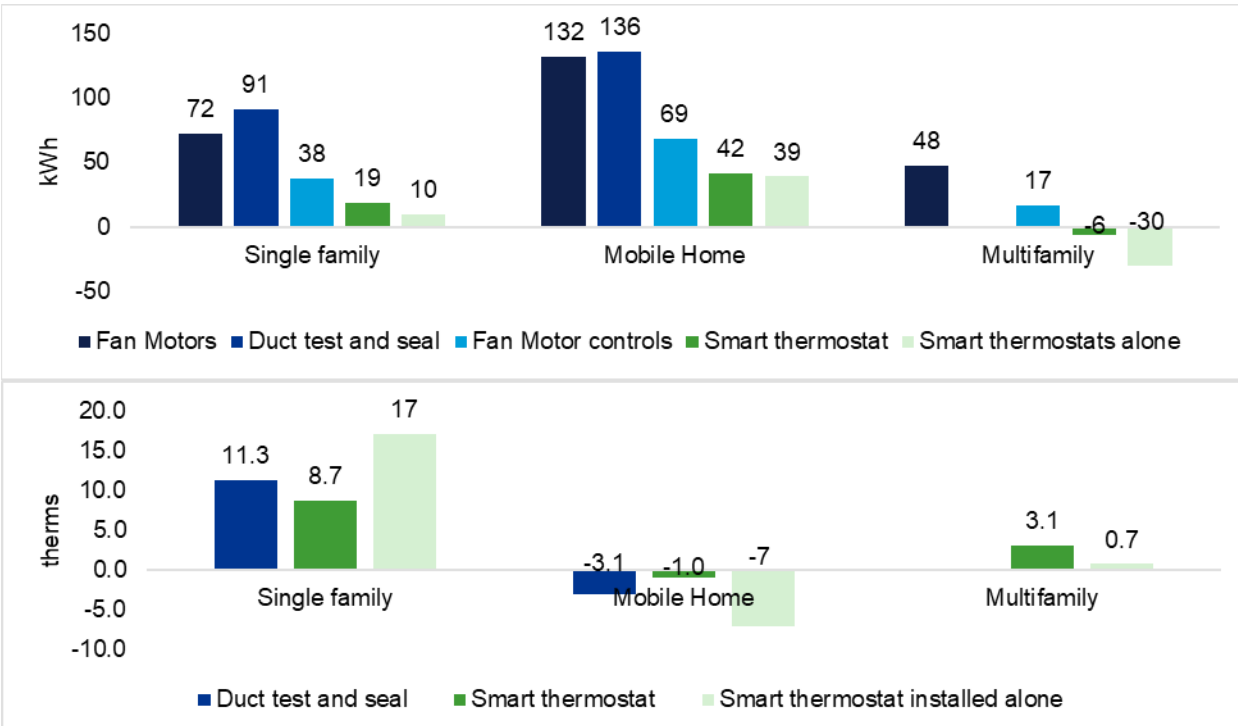


Table 1-3 provides evaluated savings for rebated smart thermostats across the three program years, which are also lower than claimed. Rebated thermostat electric savings ranged from 54 to 81 kWh per home while gas savings have remained between 2 and 3 therms per home over the three years. The incidence of key changes associated with COVID-19 were similar between the participants with rebated smart thermostats and their matches. Thus, the electricity and gas results for this measure are reliable for PY2020.

Table 1-3. Evaluated smart thermostat savings per home for rebate programs, PY2018 - PY2020

Fuel	PY2018	PY2019	PY2020
Electric savings per home (kWh)	72	54	81
Gas savings per home (therms)	2.1	2.7	2.3

[11] These participants also reported higher incidence of job losses and related adverse effects (discussed later in this summary), which could have resulted in greater occupancy changes and as a consequence lost opportunities for savings through smart thermostats summer setbacks.

1.4.2 Savings shape

In order to understand when the installed residential HVAC measures deliver electric savings, DNV conducted a savings shape analysis, which provides average electric savings by hour of the day. Figure 1-3 provides the savings shapes for homes that did not install a smart thermostat. Figure 1-4 provides savings shapes for a subset of homes that installed only smart thermostats. The non-thermostat savings have smooth, well-behaved shapes that are consistent with expectations for energy efficiency measures like fan motors and duct sealing that reduce consumption proportionally to the end use consumption. Smart thermostats have an element of user behavior which affects savings delivered unlike the other measures that do not.

Figure 1-3. Direct install average hourly savings for homes without smart thermostat installations

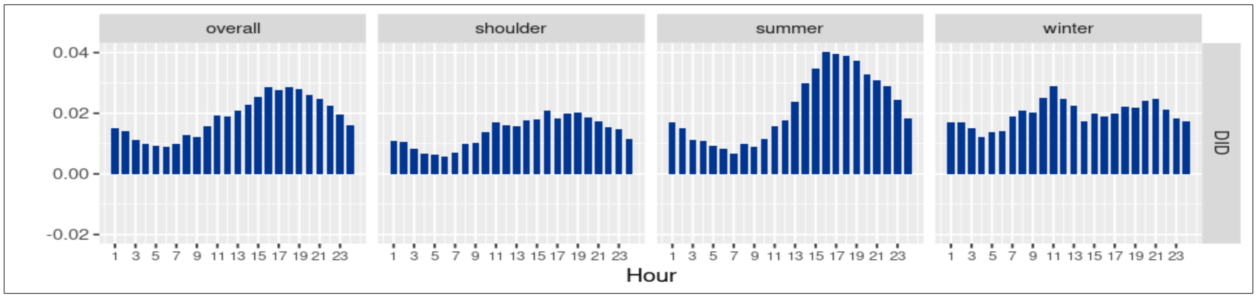
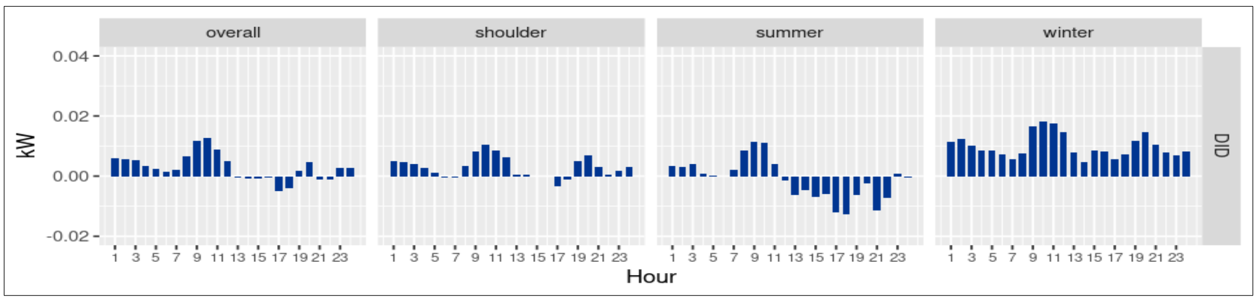


Figure 1-4. Direct install average hourly savings for homes with only smart thermostat installations



1.4.3 COVID-19 effects

California declared a state of emergency in March 2020 due to the COVID-19 pandemic and went into a lockdown. The ripple effect of these events was felt by program implementers with direct install program installations coming to a halt and only picking up steam again in the latter half of the year. Customers experienced a sustained impact of the COVID-19 pandemic that continued through the year as disrupted work and school schedules and remote options changed household occupancy and energy use patterns. The pandemic also had a direct impact on employment for customers due to job loss or reduced hours at work and increased uncertainty around household income.

The PY2020 smart thermostat and residential HVAC participant and non-participant surveys included a series of questions that asked respondents about changes in employment status, wages, and household occupancy they may have experienced since the onset of the COVID-19 pandemic in March 2020. Responses to these questions are summarized in Table 1-4 below. Results indicate that:

- Rebate program participants experienced COVID-19 impacts comparable to their matched non-participant counterparts.
- Direct install program participants experienced significantly higher COVID-19 impacts compared to their matched non-participant counterparts and rebate program participants and matched non-participants.

- All groups had a significant proportion of customers who indicated energy insecurity. Energy insecurity is defined as the inability of a household to meet its basic energy needs for heating, cooling, lighting, and other essential end uses. The results from the PY2020 statewide residential HVAC impact evaluation survey have some parallels to the national statistics related to energy insecurity. [12] The “heat or eat” dilemma would have been particularly exacerbated due to the increased occupancy in households due to lockdowns and remote work/schooling for large segments of the population.

Table 1-4. Self-reported impacts due to COVID-19, PY2020 Participants and Matched Non-participants

	Non-Participants Matched to Rebate PY2020 (n=4,448)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=3,403)	PY 2020 Direct Install Participants (n=925)
Group notation[13] / **COVID-19 impacts**	**a**	**b**	**c**	**d**
Unemployment by one or more household member	20%[b]	19%[d]	19%	29%[c]
Lost wages by one or more household member	25%[b]	24%[d]	23%	32%[c]
Unable to pay some or full bill in the last year	10%[b]	6%[d]	13%	24%[c]
“Heat or eat” - Forewent basic necessities to pay energy bill in the last year	18%[b]	16%[d]	23%	36%[c]
Kept home at an unsafe/unhealthy temperature in the last year	8%[b]	6%[d]	7%	10%[c]

1.4.4 Demand response program participation

The CPUC adopted supply and demand side requirements to ensure adequate electric power to prepare for potential extreme weather in the summers of 2022 and 2023 in its Phase 2 Decision.[14] In this Decision, the CPUC also recommended that all residential customers not currently enrolled in existing supply-side DR programs be considered eligible to participate and automatically enrolled in the residential Emergency Load Reduction Program (ELRP).

The participant and non-participant surveys conducted in this PY2020 residential HVAC impact evaluation included questions aimed at gauging respondent interest in participating in DR programs. Respondent interest in participating in DR programs is summarized below (Table 1-5). While a relatively low 2% - 14% of rebate and direct install program participants and their matched non-participant counterparts indicated that they were already enrolled in a DR program, 13% - 19% of those not currently enrolled indicated that they were very interested and over 50% of those not currently enrolled expressed some level of interest[15] in participating in a DR program.

Table 1-5. Customer interest in DR programs

Demand Response	Non-Participants Matched to Rebate PY2020 (n=4,448)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=3,403)	PY 2020 Direct Install Participants (n=925)
	a	**b**	**c**	**d**
Already enrolled in demand response	2%[b]	14%[d]	3%[d]	8%
Very interested in demand response	14%[b]	19%[d]	14%[d]	13%
Neutral to very interested in demand response	56%[b]	58%[d]	53%[d]	50%

[12] https://www.eia.gov/todayinenergy/detail.php?id=37072

[13] Significant differences in reported statistics between pairs of columns are denoted by superscripts as follows: Rebate non-participants versus Rebate participants – b, Rebate participants versus Direct install participants– d, Direct install non-participants versus Direct install participants – c.

[14] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M427/K639/427639152.PDF

[15] Respondents who rated their level of interest as 5 on a five-point interest scale are characterized as Very Interested and those who rated their interest as 3 – 5 (Neutral to Very Interested) are characterized as indicating some level of interest in participating in a DR program.

1.5 Study strengths and limitations

We summarize study strengths and limitations below.

- **Strengths.** The gross savings methods for both programs are based on observed consumption changes across thousands of homes, and control for other changes that might have affected consumption through use of matched comparison groups. The method for direct install programs combines the advantages of this consumption data analysis with engineering models informed by participant characteristics from tracking as well as California general characteristics from the most recent California Residential Appliance Saturation Study (RASS 2019).[16] The approach to determine program influence uses systematic surveys and analysis consistent with established methods while the surveys also provide insights into comparison group validity.
- **Limitations.** The direct-install consumption data analysis calibrates measure-level engineering savings estimates to observed consumption and changes in consumption. As a result, the total savings estimate across all measures is well grounded, but there is some uncertainty in the allocation of this total among the measures.

1.6 Recommendations

The key findings from the evaluation and the recommendations stemming from it are summarized in this section (Table 1-6)**.**

Table 1-6. Key findings and Recommendations

 Key findings	 Recommendations & Implications
1. Realization rates for rebated smart thermostats improved in PY2020 because ex-ante savings have been reduced based on prior evaluation results. Direct install smart thermostats, fan motor replacements, and fan motor controls continue to have low gross realization rates. Duct testing and sealing continue to have high realization rates.	Continue to adjust ex-ante savings for other measures similarly, particularly for those with fairly stable savings patterns from past evaluations.
2. Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the end use consumption and deliver savings consistently across all seasons.	PAs should continue to include these measures in the residential HVAC program portfolio.
3. While the PY2019 evaluation found no gas savings for smart thermostats delivered through direct install programs, the PY2020 evaluation identified gas savings for this measure that are 40% of claimed savings.	Since these results paint a mixed picture, DNV recommends additional study to examine the consistency and stability of the gas savings potential for smart thermostats.

[16] DNV Energy Insights USA, Inc. 2020. 2019 California Residential Appliance Saturation Study. California Energy Commission (CEC). Final statewide survey dataset obtained from the California Energy Commission (CEC).

 **Key findings**	 **Recommendations & Implications**
4. Over half of those not currently enrolled in a DR program expressed some level of interest in participating in a DR program.	PAs should include information on the benefits of DR program participation for customers that receive free or subsidized smart thermostats through EE programs and implement an option to enroll willing customers at the point of installation.
5. For direct install programs, relatively high NTGR and higher burden from COVID-19 suggested by survey results indicate that these programs are reaching the right population segments.	Maintain targeting and outreach to these customers.
6. For direct install programs, survey data collection was hampered by lack of reliable information regarding parties responsible for decision-making and lack of contact information for end users for direct install programs.	Prescribe program tracking data requirements that include capturing these specifics.
7. We lack visibility into the electricity consumption of a large number of gas customers for whom electric savings were claimed by SCG. Hence these households are unable to inform the electric savings estimates.	Facilitate cross PA identification of customer account IDs for program participants residing in territories served by different electric and gas PAs.

2 INTRODUCTION

2.1 Program description and participation

DNV is evaluating four residential heating, ventilation, and air conditioning (HVAC) measures installed in program year 2020 (PY2020). These measures, which include smart communicating thermostats, fan motor replacements, fan controls, and duct testing and sealing, improve the operation of the HVAC system and reduce the amount of energy it uses.

Smart communicating thermostats (SCT) allow users to control their home's HVAC system. SCTs' primary function is to enable users to maintain desired temperature levels. Their internet connectivity also provides additional 'smart' means of managing a home's energy use from anywhere and optimizing the performance of the HVAC system through automatic setbacks based on occupancy sensing capabilities. The ability to manage energy use remotely through internet connected devices and make automated adjustments to the setpoint of the HVAC system provides additional and potentially improved energy management while maintaining comfort. In PY2020, SCT vendors also offered thermostat optimization, a process designed to save more energy through additional setpoint adjustments that balance each home's response to weather conditions and energy use habits.

Fan motor replacement involves replacing existing permanent split-capacitor central HVAC fan motors with high-efficiency brushless fan motors. These brushless fan motors require less energy to move air through the HVAC system reducing electricity consumption during all hours of the system's operation including peak demand periods.

A fan motor control is a retrofit add-on measure that delays turning off the fan motor at the end of an air conditioning or heating cycle to increase the HVAC system's effectiveness by extracting the remaining cooling or heating potential. Newer HVAC systems have shorter duration built-in fixed-length supply fan delay features.[17] Add-on fan controllers can have either fixed or variable fan-off delay features that often run longer than the built-in fan-off delay.[18].

Duct testing and sealing involves testing and sealing residential ductworks to reduce leakage losses to specified levels. By reducing leakage, more of the heating or cooling is delivered directly to the occupied space rather than lost to leakage outside the occupied space.

In PY2020, six California program administrators (PAs)[19] offered these technologies through 21 different programs (Table 2-1). The programs provided a mix of energy efficiency measures including the evaluated HVAC measures using direct install and rebate delivery mechanisms.

Table 2-1. Programs offering residential HVAC measures, PY2020[20]

PA	Program Name	Target	Delivery Method	Measures offered
PG&E	Residential Energy Efficiency - PGE21002	All residential customers or Single-family	Rebate (34%)	Smart thermostats, motor replacement, other HVAC measures, pool pumps, plug load and appliances, roof and wall insulation, and water heating measures
SCG	RES-Residential Energy Efficiency Program - SCG3702			
SCG	RES-Plug Load and Appliances - POS - SCG3703			
SDG&E	SW-CALS-Plug Load and Appliances-POS Rebates - SDGE3204			
PG&E	Residential HVAC - PGE21006			
SCE	Plug Load and Appliances Program - SCE-13-SW-001B			

17 There are currently no federal, state, or regional codes that impact fan controllers for residential air conditioners. However, Chapter 4, Article 4, Section 1605.1(c), Table C.3 of California's Title 20 code requires split system air conditioners installed after January 1, 2015, to have a minimum SEER rating of 14.0. R799, which have built-in fan controllers.

18 This is in contrast to some smart thermostats that are capable of shorter fan-off delays. Other smart thermostats have a function that preemptively turns off the compressor and condenser fan motors while maintaining the supply-fan airflow.

19 Marin Clean Energy (MCE), Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas and Electric Company (SDG&E), and Tri-County Regional Energy Network (3C-REN).

20 Although the Home Upgrade Program (HUP) and Advanced Home Upgrade Program (AHUP) also offered smart thermostat measures, claims from these programs are not included in the smart thermostat evaluation. HUP and AHUP program savings are evaluated at the whole home level and not at the measure level.

PA	Program Name	Target	Delivery Method	Measures offered
TCR	Residential Direct Install - TCR-Res-001	All residential customers	Direct Install (66%)	Comprehensive mix of measures, including smart thermostats, motor replacements, fan controls, and duct sealing
PG&E	Residential Energy Fitness program - PGE210011			
MCE	Single Family Direct Install Standalone - MCE08			
SCE	Residential Direct Install Program - SCE-13-SW-001G			
SCG	RES-Direct Install Program - SCG3820			
SCG	RES-LADWP HVAC - SCG3836			
SCG	RES-CLEO - SCG3762			
PG&E	Direct Install for Manufactured and Mobile Homes - PGE21009	Mobile Home		
SCE	Comprehensive Manufactured Homes - SCE-13-TP-001			
SCG	RES-Manufactured Mobile Home - SCG3765			
SDG&E	3P-Res-Comprehensive Manufactured-Mobile Home - SDGE3279			
MCE	Multifamily Direct Install Standalone - MCE05	Multifamily		
PG&E	Enhance Time Delay Relay - PGE21008			
SCE	Multifamily Energy Efficiency Rebate Program - SCE-13-SW-001C			
SCG	RES-MF Direct Therm Savings - SCG3763			

Source: PA Tracking Data filed with the CPUC

Table 2-2 provides claimed electric installations and savings (kWh) by PA and delivery type in PY2020. It shows that most installations and claimed electric savings were from direct install programs. In addition, demand claims and savings (kW) were almost all from direct install measures.

Table 2-2. Residential HVAC-measure installations and electric savings claims by PA, PY2020

PA	Electric Installations		Gross Program Electric Savings (kWh)		Gross Program Electric Savings (kW)	
	Direct Install	Rebate	Direct Install	Rebate	Direct Install	Rebate
MCE	435		40,046		2	
PG&E	13,024	10,673	2,767,551	922,805	979	0.3
SCE	27,583	15	8,732,145	2,598	3,887	
SoCalGas	13,640	8,882	1,325,901	1,312,332	110	
SDG&E	3,328	5,560	1,116,861	638,667	387	
TCR	47		1,046			
Statewide	**58,057**	**25,130**	**13,983,549**	**2,876,402**	**5,366**	**0.3**

Source: PA tracking data filed with the CPUC

Table 2-3 provides gas installations and savings from direct install and rebate programs in PY2020. Direct install programs claimed gas savings from duct sealing and smart thermostats while rebate programs claimed gas savings from smart thermostats only. The number of installations were higher for direct install programs but claimed gas savings were about the same from the two delivery channels reflecting higher savings claims per installation for rebate programs.

Table 2-3. Residential HVAC-measure installations and gas savings claims by PA, PY2020

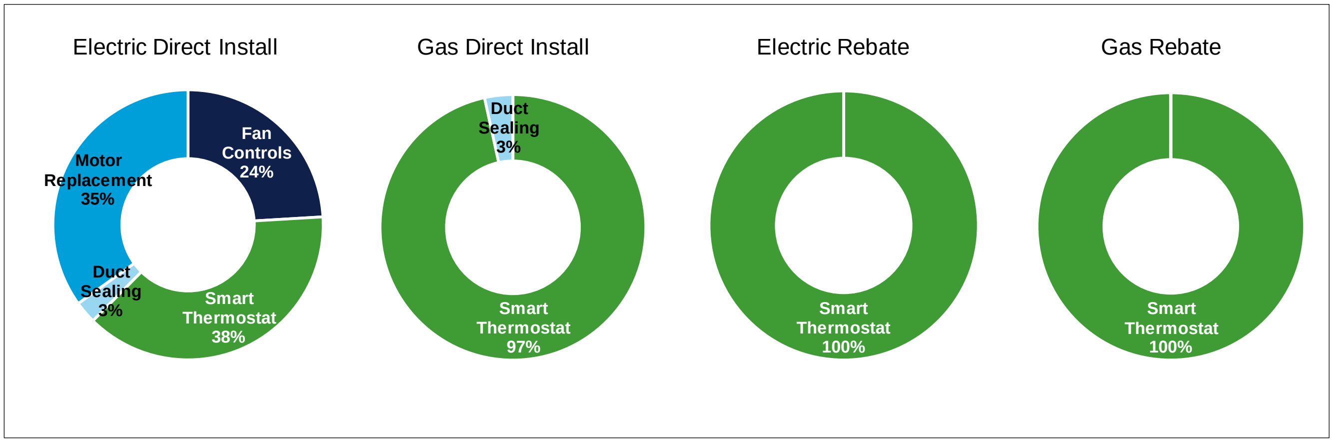
PA	Gas Installations		Gross Program Gas Savings (therms)	
	Direct Install	Rebate	Direct Install	Rebate
MCE	435		9,321	
PG&E	6,345	10,449	49,350	228,589
SCE	13,590	15	150,191	276
SoCalGas	17,145	8,882	128,877	101,597
SDG&E	1,249	4,836	8,129	44,023
TCR	47		793	

PA	Gas Installations		Gross Program Gas Savings (therms)	
	Direct Install	Rebate	Direct Install	Rebate
Statewide	**38,811**	**24,182**	**346,661**	**374,485**

Source: PA tracking data filed with the CPUC

Figure 2-1 summarizes the percent of claimed electric and gas savings from each residential HVAC measure by delivery channel. Direct install programs claimed electric savings from all four HVAC measures and gas savings from duct sealing and smart thermostats. Rebate programs claimed both electric and gas savings almost entirely from smart thermostat installations. In all cases, the percent of savings claimed from smart thermostats is higher than for all other measures.

Figure 2-1. PY2020 percent electric and gas claimed savings by measure and delivery type, PY2020



The PY2020 residential HVAC programs targeted all eligible customers living in single-family, multifamily, and mobile homes. Since the programs claimed the majority of their savings from smart thermostats, we examined the proportion of electric and gas savings claims by dwelling type and delivery channel for this technology.

Table 2-4 provides the percent of smart thermostats with electric and gas claims by dwelling type and delivery channel. The second and third columns of the table provide percent electric and gas claims in different dwelling types by delivery channel. The last two columns provide the percent claims for which participant IDs were available for evaluation. In these columns, percent electric claim values do not include SCG installations while percent gas claims do not include SCE installations. This is because there are no electric participant IDs with which to evaluate SCG installations and no gas participant IDs with which to evaluate SCE installations.

In PY2020, the majority of claims (46% with electric savings and 43% with gas savings) were installed in single-family homes through rebate programs. While the majority of direct install smart thermostats were installed in multifamily homes, a lower percentage of direct install electric claims had participant IDs available for evaluation.

Table 2-4. Smart thermostat claims by program type, PY2020

Program Type	All Claims		Excluding claims that can't be linked to account identifiers	
	Percent Claims with Electric Savings (N = 55,120)	Percent Claims with Gas Savings (N = 56,774)	Percent Claims with Electric Savings (N = 36,007)*	Percent Claims with Gas Savings (N = 45,954)*
Residential Rebate**	46%	43%	45%	53%
Multifamily Direct Install	25%	23%	16%	28%
Mobile Home Direct Install	12%	12%	12%	10%
Single Family Direct Install	17%	23%	26%	9%

*Counts reflect claims with participant IDs (i.e., excluding electric claims for SCG and gas claims for SCE)

** Over 90% of rebate program installations involved single-family homes

Figure 2-2 below shows the patterns of PY2020 residential HVAC measure installations by climate zone. While the geographic concentration of all smart thermostat installations appears more diffuse than those of the other measures, direct install smart thermostat installations were concentrated in climate zones 10 (at 20%) and 13 (at 19%). The other three direct install residential HVAC measures were also concentrated in certain climate zones. Duct sealing installations were predominantly installed in climate zone 10 (at 57%) while motor replacements and fan controls were predominantly installed in climate zone 13 (at 49% each).

Figure 2-2. Geographic concentration of installed residential HVAC measures by climate zone, PY2020

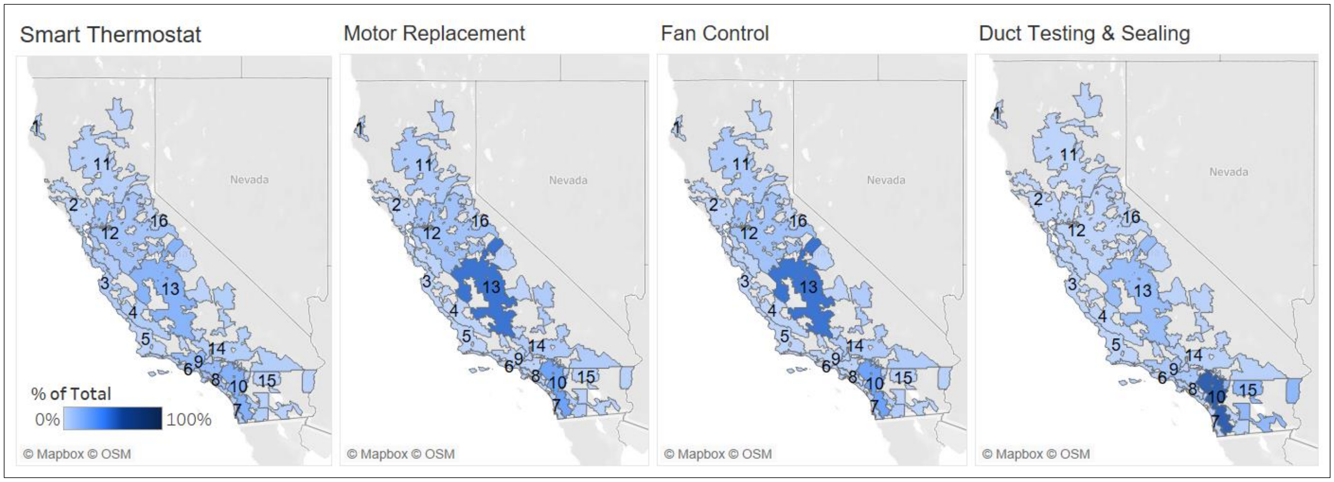


Table 2-5 provides another view of the geographic concentration of residential HVAC measure installations in PY2020. The table indicates that rebated smart thermostats (mostly installed in single family homes) had a geographically diffuse installation pattern. The normal (typical meteorological year – TMY) cooling and heating degree days (CDD and HDD)[21] of the climate zones where rebated smart thermostats were installed indicate variation in cooling and heating conditions; some rebated smart thermostats were installed in regions with some heating (climate zones 3 and 4) or cooling (climate zone 12) needs while others were installed in areas with mild heating and cooling needs (climate zones 7).[22] On the other hand, direct install measures were concentrated in climate zones 10 and 13, with notable cooling and heating needs. In general, direct install measures were installed in climate zones designated as hot (shaded grey in the table below) by California's 2021 Summer Reliability Decision.[23] These are climate zones where the installed HVAC measures are likely to provide cooling and heating savings.

[21] 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°F and the average daily temperature on that day is 70°F, 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°F was used for both CDD and HDD in the table.

[22] Areas with the highest cooling needs in the state have CDD values that are above 2,000 while areas with significant heating needs have HDD values that exceed 3,000.

[23] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M427/K639/427639152.PDF

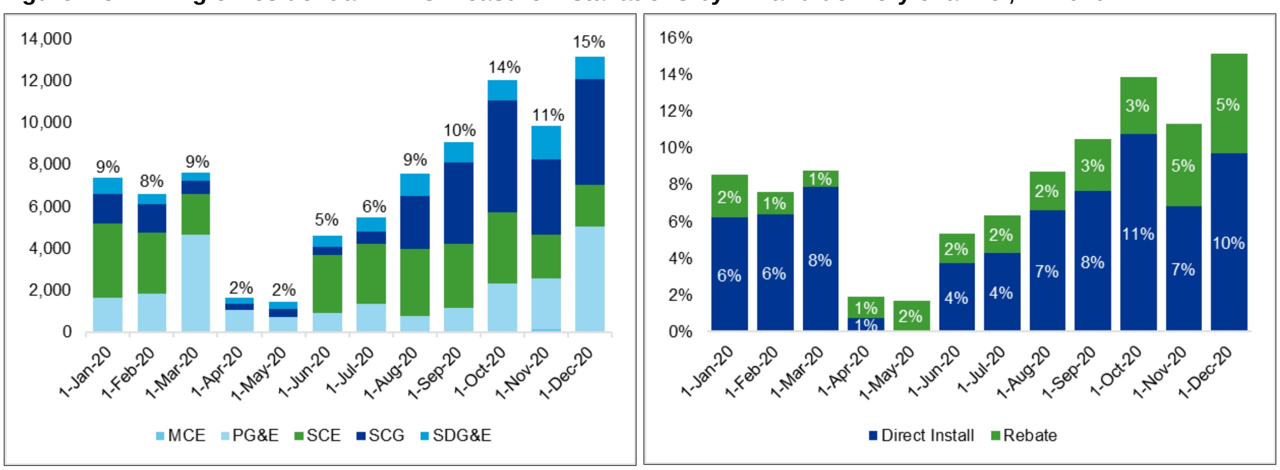
Table 2-5. Direct install and rebate residential HVAC installations by climate zone, PY2020

Climate zone	Normal HDD	Normal CDD	Direct Install Program Installations			Rebate Program Installations		
			Single family	Multifamily	Mobile Home	Single family	Multifamily	Mobile Home
1	4,305	120	0	0	0	43	0	0
2	3,719	147	43	4	3	505	17	6
3	2,591	474	40	1	0	2,394	354	6
4	2,287	507	9	0	0	2,005	253	5
5	2,406	161	22	3	13	336	11	1
6	1,453	752	95	386	132	1,497	2	0
7	1,359	797	0	0	0	3,264	0	0
8	1,176	959	137	3,808	483	1,840	2	0
9	1,253	1,325	1,850	3,391	665	4,149	11	0
10	1,592	1,101	13,028	329	7,862	3,188	0	2
11	2,664	1,575	15	440	898	741	13	11
12	2,491	1,453	326	36	2,275	3,064	117	13
13	2,460	1,941	7,328	8,271	2,722	1,089	23	6
14	1,642	2,897	3,452	401	359	144	0	0
15	1,047	4,480	397	2	2,058	258	1	0
16	3,338	1,402	186	1	91	153	1	1
Total Residential HVAC Installations			**26,928**	**17,073**	**17,561**	**24,670**	**805**	**51**

Climate zones designated as hot by the 2021 Summer Reliability decision are shaded grey[24]

Figure 2-3 summarizes the timing of residential HVAC measure installations by PA and delivery channel in PY2020. Both panels in the figure indicate precipitous drops in program activity in April and May of 2020, with almost no direct install activity reported for May after the stay-at-home orders due to the COVID-19 pandemic. Installation activity started increasing in June and was highest in the last three months of PY2020.

Figure 2-3. Timing of residential HVAC measure installations by PA and delivery channel, PY2020



2.2 Evaluation objectives

DNV's research objectives in this evaluation were to:

- Estimate the electric and gas savings associated with PY2020 installations of smart thermostats, fan motor replacement, fan motor controls, and duct testing and sealing.
- Determine the extent to which evaluated savings estimates matched claimed savings.

24 Ibid.

- Estimate free-ridership by measuring what proportion of program installations would have occurred in the absence of the programs.

DNV 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 used for the data processing and analysis phases of the residential HVAC evaluations.

3.1 Data sources

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

- **Tracking data:** DNV sourced information about program participation at the claim level from tracking data that the PAs filed with the CPUC in the California Energy Data and Reporting System (CEDARS).
- **Program participant data.** DNV obtained program-related information, including brand of devices installed and participant contact information, at the customer account level from each PA.
- **Energy use data:** DNV obtained energy consumption data at the customer account level from the PAs to analyze energy use patterns and changes due to the residential HVAC measures.
- **Customer data:** Supplementary information (location, climate zones, rates) on both participating and non-participating customers used in the study were sourced from utility customer information tables obtained from the PAs. The PAs also provided additional household-level information (household size and age composition, income etc.) for the evaluation. Data were at the customer account level.
- **Survey data:** The study used data from primary research (surveys) to understand customer engagement with smart thermostats and the other residential HVAC measures and their effect on energy use at the customer account level for the responding sample.
- **Weather data:** Weather data were sourced from the National Oceanic and Atmospheric Administration (NOAA) and climate zone 2020 reference temperature files (CZ2020) to include in regression models accounting for weather sensitivity.[25] CZ2020 provides typical meteorological year (TMY) 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.[26] Data were at the hourly level for each station.

DNV investigated the feasibility of using device data from thermostat vendors and was not able to acquire data in time for use for the evaluation in PY2020. DNV was able to reach an agreement with vendors to use summarized device data late in the evaluation process and will work to incorporate these in upcoming studies.

Table 3-1 summarizes the various sources of data used in the smart thermostat evaluation in PY2020.

Table 3-1. Data sources used for residential HVAC evaluation, PY2020

Data	Source	Period Covered	Contents
Tracking Data	CPUC Tracking 2018, 2019 and 2020 Data	2018-2020	Program information (IDs, claims)
Program Participant Data	PAs	2019-2020	Program details (devices installed, dates, participant contact info)
Energy Use Data	PAs	May 2019 - November 2021	Monthly billing electric and gas data, and hourly electric and daily gas AMI data

[25] 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.

[26] https://ww2.energy.ca.gov/maps/renewable/building_climate_zones.html

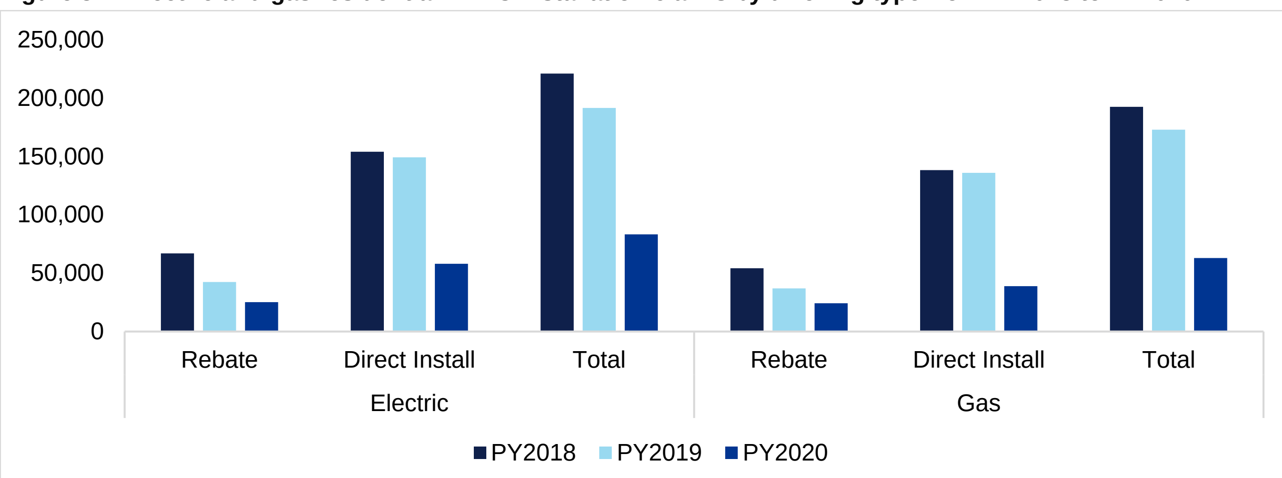
Data	Source	Period Covered	Contents
Customer Data	PAs	2018-2020	Customer location (zip code), climate zones, and household-related information (household size, age composition, income, ownership status)
Survey Data	Primary Research	2020	Customer and property manager surveys - program influence, dwelling characteristics, energy use behavior, demographics
Weather Data	NOAA and CZ2020 from CALMAC	January 2018 - December 2021	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 by the PAs.[27] CEDARS provides counts of all program installations and the amount of energy savings these installations are expected to generate.

The summary of PY2020 installation timing in the previous section indicated that the number installations dropped sharply with the onset of the pandemic-related stay-at-home-orders starting in March 2020. Although program activity had fully resumed in the last quarter of the year, the number of PY2020 installations were lower than in past years. Figure 3-1 summarizes electric and gas residential HVAC installations by dwelling type from PY2018 to PY2020. Across both delivery mechanisms and fuel types, residential HVAC evaluations were lower by 65% and 60% compared to PY2018 and PY2019 respectively, dropping from approximately 220,000 and 191,000 electric claims in PY2018 and PY2019 to approximately 83,000 electric claims in 2020 with analogous numbers for gas claims.

Figure 3-1. Electric and gas residential HVAC installation claims by dwelling type from PY2018 to PY2020



Given the reduction in PY2020 program activity, DNV augmented the data used in the analysis with participants from the second half of PY2019. The additional PY2019 participants were not included in any prior evaluation and provided a more robust basis for the evaluation. Both rebate and direct install savings for PY2020 are based on consumption data analysis using installations from May 2019 through the end of 2020.

3.1.2 Measure bundles

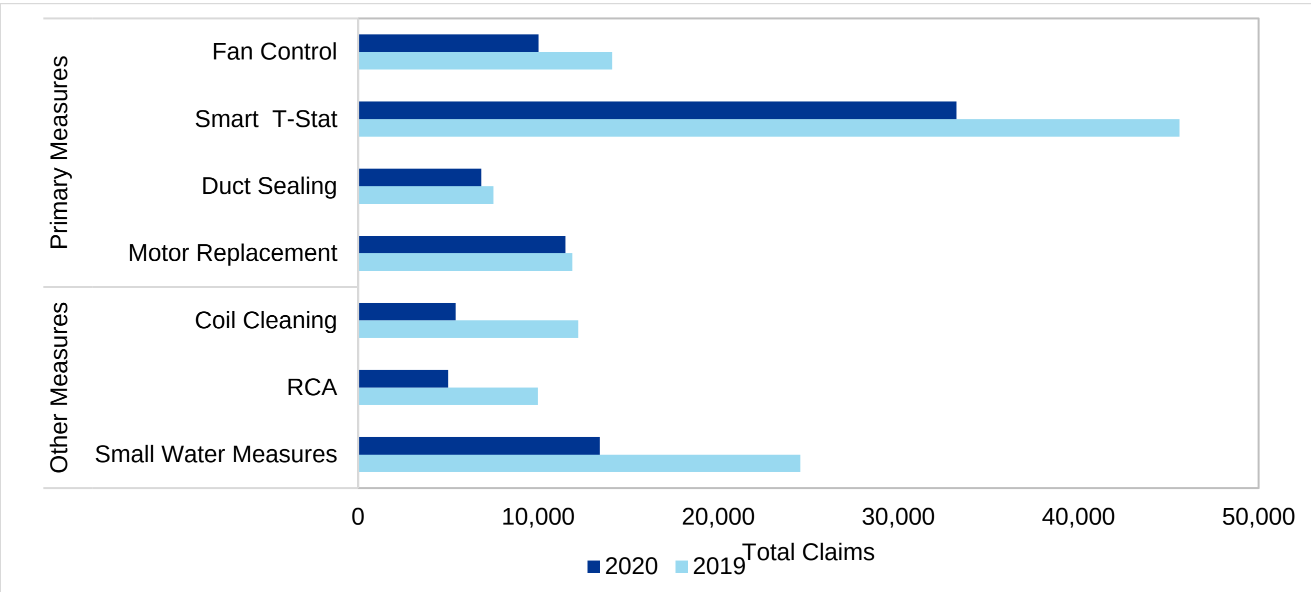
Participants in rebate programs primarily installed smart thermostats as a stand-alone measure and the evaluation used participant data from those stand-alone installations. Participants in direct install programs installed the evaluated measures as part of a bundle. DNV assessed the tracking data to understand the extent of measure overlaps for direct install programs

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

and to identify the homes that can be included in the residential HVAC evaluation. The tracking data analysis indicated that direct install programs offering the residential HVAC measures also installed other measures.

Figure 3-2 provides the total number of claims for HVAC and other measures with which they were installed in the second half of PY2019 and all of PY2020. DNV evaluated four of the HVAC measures (primary measures) listed in the figure in PY2020 and included the rest of the measures (other measures) in the analysis to separate whole-home savings into the relevant constituent parts. We did not include other measures that overlapped minimally with the primary measures in the evaluation. This approach still preserves data from almost all participants with measures of interest while limiting the number of overlaps with non-evaluated measures included in the analysis.[28]

Figure 3-2. Measures and participating homes through direct install programs, May 2019 – December 2020



3.1.3 Energy consumption data

DNV obtained consumption data from the PAs for both electricity and gas at multiple levels of granularity: billing month, daily, and hourly. Billing data were used as a means of identifying customers who did not get program-sponsored residential HVAC measures (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 served as the basis for site-level modeling. Additional information on this process is provided in Appendix . Finally, hourly data were included in models used to estimate the effect of the program/measure on hourly energy demand. We obtained all energy use data from each PA for program participants and selected non-participants.

We prepared billing data by removing duplicate reads, sites with total zero energy use for the year, and reads that correspond to onsite solar energy production. We also aggregated the billing data to the bill month so that there are 12 reads in a year; billing values that reflect multiple smaller read intervals were summed to the monthly level. We included only customers who have a full year of matching period data in the analysis.

To prepare the daily gas data, we screened the daily data for duplicate reads at the customer and day level and aggregated or removed duplicates depending on the context. We also screened the data for negative values and for values that reflect

[28] We evaluated the electric savings of four measures (smart thermostats, fan motor replacements, fan controls, and duct testing and sealing). We evaluated gas savings for two of these measures (smart thermostats and duct testing and sealing), which had positive gas savings claims. While we accounted for the gas penalty from the installation of fan motor replacements, we did not evaluate the negative gas savings claims for this measure. There were no gas savings claims for fan controls.

no gas use (annual value of zero therms) over the analysis time period. Finally, we only included data from customers with full data from the matching period through the evaluation period.

To prepare the hourly electric data, we also used screening procedures. First, we excluded households with onsite solar production because there was no way to determine their true energy consumption given the available data.[29] Second, we excluded days missing more than four hourly reads. Third, we excluded days with zero total consumption.

Finally, for both daily gas and hourly electric data, we included data for only those customers with at least 90% of daily values in both the pre- and post-program period.[30] After screening the data, we checked it against billing records to ensure the integrity of the data.

Table 3-2 presents the number of customers for whom consumption data were considered and used in the study. The table indicates starting household counts from the tracking data considered for use in the evaluation and for whom we requested and received data; the number of customers without onsite solar, and finally customers with interval (AMI) data with the requisite pre- and post-data of at least 328 days available for the analysis. The table provides the breakdown by fuel.

Table 3-2. Smart thermostat customer counts used in the evaluation by PA and fuel type, PY2020

Participant Data Attrition	PG&E Electric	PG&E Gas	SDG&E Electric	SDG&E Gas	SCE Electric	SCG Gas
Customers with evaluated measures (PY2019 and PY2020 installations)	36,680	36,027	8,893	7,715	22,205	47,905
Customers for whom data was requested*	35,923	35,268	8,893	7,715	22,205	47,878
Customers for whom some data was received	32,643	29,476	8,591	6,323	22,137	47,844
Customers with data and not net-metered	26,310		5,747		16,501	
Customers with matched and sufficient data used in the analysis**	17,024	24,794	2,293	3,869	11,758	40,255

*Customers that installed evaluated measures and had significant overlap with non-evaluated measures
**Customers without solar (electric) and at least 90% of pre-and post-installation period data

Our analysis uses data from about 45% to 80% of participants, except for SDG&E electric where we used data from about a quarter of the participants. The notable drop in SDG&E electric participant data is due the presence of a large number of homes with onsite solar.

3.1.4 Weather data

Observed and typical meteorological year (TMY) data are important inputs for addressing changing weather conditions and their effect on energy consumption. DNV sourced hourly weather data for 97 National Oceanic and Atmospheric Administration (NOAA) weather stations across California that provide historical weather observations and for which TMY series were developed, most recently, CZ2020. CZ2020 have TMY 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 2018 typical year weather data to reflect more recent weather trends.[31]

DNV applied the following data filtering protocols in line with CalTrack recommendations and used weather data from 64 weather stations that have complete and usable data in the analysis.[32] The filtering protocols include:

- Interpolating gaps of up to six consecutive hours

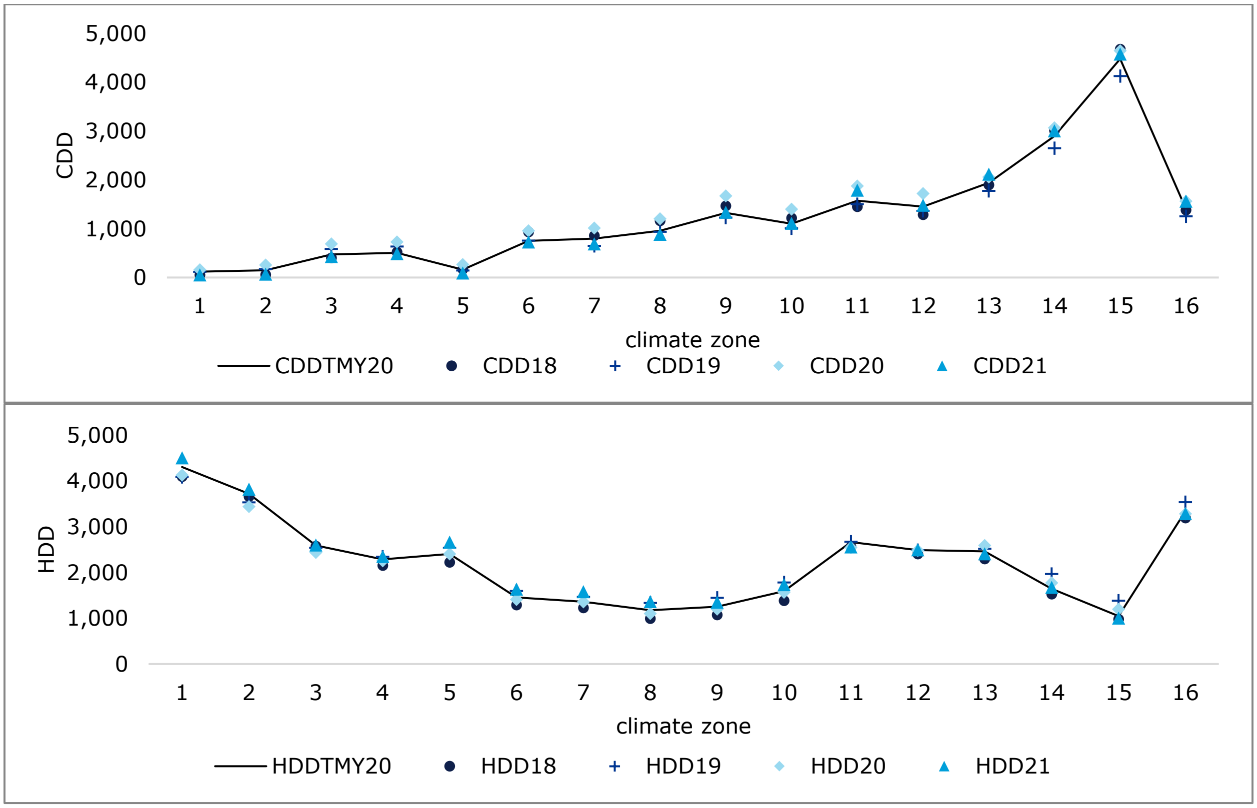
[29] Utility records provide net-metered electricity use, which reflects the difference between delivered and received kWh, but not the amount of onsite solar production.
[30] These energy consumption data requirements are in line with CalTrack recommendations. http://docs.caltrack.org/en/latest/methods.html#section-2-data-management
[31] http://calmac.org/weather.asp
[32] http://docs.caltrack.org/en/latest/methods.html#section-2-data-management

- Calculating and using daily average temperatures for days with at least 12 hourly temperature reads
- Including stations that have at least 90% of the data for each year needed in the analysis

Figure 3-3 provides a summary of cooling degree-days (CDD) and heating degree-days (HDD) used in the study. DNV used 2020 TMY data to weather normalize consumption in this study. In general, weather normalization controls for the effect of weather variation by putting energy consumption on the same normal weather terms across time.

The 2020 TMY values reflect more recent weather patterns including warmer summers and more mild winters. The figure indicates areas of the PAs' service territories that have significant cooling needs (CZ13 through CZ15) and heating needs (CZ2 through CZ5, CZ11, and CZ16). The figure also illustrates the variation of the actual weather CDDs and HDDs over the analysis period relative to normal CDDs and HDDs that are used to state energy consumption on the same weather basis. Such weather normalization facilitates the comparison of energy consumption after controlling for the effect of weather.

Figure 3-3. Summary of weather data, PY2020



3.1.5 Survey data

DNV surveyed participants, non-participants, property managers, and contractors to inform program attribution and gather data that provide context to savings estimates.

3.1.5.1 Occupant surveys

DNV administered participant surveys to customers who were the decision makers for residential HVAC installations in their households and either availed themselves of a program rebate or accepted free installed HVAC measures. The primary objective of these surveys was to inform estimates of free-ridership (and the complementary NTGRs or program attribution estimates). Surveys also gathered information on thermostat use, satisfaction, energy use behavior, demand response participation and interest, and the effect of COVID-19.

DNV 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 the residential HVAC or other utility energy efficiency programs. The primary objective of the non-participant surveys was to provide a reference point related to COVID-19 impacts, energy use behavior, and demand response program participation.

3.1.5.2 Property manager surveys

Direct install programs provide customers with residential HVAC measures at no cost. For multifamily residential HVAC measures installed through direct install programs, property managers are the decision makers responsible for these installations. DNV interviewed property managers to inform free-ridership estimates for such installations.

3.2 Gross savings

This section presents the methodology DNV used to estimate savings of residential HVAC measures. DNV used installations from the second half of PY2019 and all of PY2020 program participants to estimate PY2020 savings for the residential HVAC measures delivered by both rebate and direct install programs. PA data in the same climate zone were combined in order to produce a single and consistent savings per measure for the climate zone.

Program tracking data indicated that the majority of rebate program participants were single-family homes receiving smart thermostats with no additional program measures. On the other hand, direct install participants were single family, multifamily, and mobile homes that installed multiple measures. Different approaches are required to evaluate the energy use impact of measures when they are installed alone versus in combination with other measures.

To evaluate rebate program installations, DNV used consumption data analysis to estimate whole-home savings. Detailed description of the consumption data analysis framework that uses two-stage modeling is provided in Appendix E. The basic method uses a difference-in-difference (DID) approach based on pre-to-post difference in normalized annual consumption (NAC) of participant and matched comparison households to estimate savings.[33] In this model, pre-post NAC (delta NAC) is specified as a function of a treatment indicator used to estimate savings. For rebate programs, the basic consumption data analysis was augmented with an adjustment to correct for a potential differential trend in energy consumption between participant and matched comparison households. Since rebate participants only installed smart thermostats, whole-home savings provides smart thermostat savings estimate for these participants.

To evaluate direct install program installations, we also used consumption data analysis to estimate whole-home savings, but an adjustment for differential trend was not required for these programs.[34] Since direct install programs typically deliver multiple measures, it is necessary to decompose whole-home savings into measure-specific savings. One approach is to use regression-based statistical decomposition of whole-home consumption changes. Statistical noise and multicollinearity make this a challenging undertaking. The physical incremental effect of a single measure depends on what other measures are also installed, complicating this approach further.

Another approach, which we used, is to allocate whole-home savings to the multiple installed measures based on engineering estimates. To the extent practical, we also used separate consumption data analysis for direct install homes that received single measures to confirm the allocation of the whole home savings. A description of the approach we used to obtain robust measure-specific savings under these conditions is detailed in Section 3.2.2.

[33] Matched comparison households used in DID models are identical to participants along relevant dimensions including consumption and are identified using matching protocols discussed in Appendix E. The matching protocol involves testing that the participants and selected matched non-participants are balanced along key load dimensions such as consumption and demographic characteristics such as household composition and size.

[34] The conditions that are conjectured to contribute to the differential trend for rebate don’t apply to direct install programs.

3.2.1 Gross savings adjustments

3.2.1.1 Rebate program trend adjustment

Similar to the PY2018 findings, the current evaluation indicates a considerable baseload increase for rebate participants compared to matched non-participants in PY2020.[35] DID models based on baseload indicate the presence of a statistically significant increase in this category of load for rebate program participants across the three dwelling types. There could be a few reasons for the pre- to the post-installation period baseload increase for participants compared to their matched counterparts. In general though, the estimated increase suggests the existence of a difference in energy consumption trends between participants and matched non-participants.

The basic model that uses delta NAC cannot provide estimates of available program savings in the presence of such energy use trend difference. While the effect of this trend difference manifests in higher baseload increases for participants relative to matched non-participants, it is also likely to affect non-baseload (heating and cooling for electric and heating for gas), the component of load that HVAC measures target. To address this, we estimated a non-baseload model that removes the trend differential. Details on the adjustment for trend differential and the model we used to estimate savings for the rebated measure are provided in Appendix E, Section 8.5.4.

3.2.1.2 Comparison group thermostat installation adjustment for direct install

DNV adjusted estimated smart thermostat savings for direct install programs to account for the installation of this measure among matched comparison households. DNV's non-participant survey included a question that asked respondents to indicate whether they had installed smart thermostats before 2018 and any time from 2018 through 2021. Non-participant installations from 2018 through 2021 overlap with participant installation and post periods. If comparison group smart thermostat installations are assumed to have the same savings effect in the matched comparison households as program thermostats, then their presence during this period will have the effect of diminishing the magnitude of estimated smart thermostat savings for participants. The adjustments to control for this effect are detailed in Appendix G, section 8.7.3.[36]

3.2.2 Decomposition of whole-home savings

Where multiple measures are installed, consumption data analysis can most accurately provide estimates of whole-home savings that occur due to the combination of all installed measures. DID model estimates provide average whole-home savings by dwelling type, which vary by site based on the measures installed. Site-specific whole-home savings that reflect savings from the installed measures at each site can be estimated using DID models. These site-specific whole-home savings can be disaggregated to measure-specific savings based on engineering model estimates.

Engineering model estimates for this purpose are derived from simulations of residential energy use based on California Database for Energy Efficiency Resources (DEER) prototypes in eQuest, an engineering simulation engine. The simulation models, discussed in more detail in Section 3.2.3 below, provide estimates of the percent reduction in load from baseline use by climate zone and housing type, for individual measures and for measure bundles offered by direct install programs.

The measure savings the engineering simulation models provide are both on a last-in basis (incremental/marginal where all other measures are assumed to be efficient) and as part of a bundle. Results from engineering simulations are used both to determine whole-home savings and disaggregate these savings to the measure-level. The whole-home model that uses engineering simulated values as input has the following specification:

$$\Delta NAC_i = \alpha_0 + \gamma E_i + \varepsilon_i$$

[35] http://www.calmac.org/publications/CPUC_Group_A_Report_Smart_Thermostat_PY_2018_CALMAC.pdf

[36] DNV did not make this additional adjustment for smart thermostats installed through rebates because the trend differential adjustment described earlier captures these effects.

where E_i, total engineering measure savings received by participant i, replaces the treatment dummy from the whole-home DID model for a more informed estimate of savings.

However, since the size of participant homes vary, we estimated models where the percent change in NAC is explained by percent measure savings provided by engineering simulation models. We also allowed for the possibility that a treatment dummy along with the informed engineering percent savings estimate may be needed to account for constant savings associated with the program installations. The measure model we estimated is thus specified as:

$$\%\Delta NAC_i = \alpha_0 + \beta T_i + \gamma\%E_i + \varepsilon_i$$

Here

$\%\Delta NAC_i$ is percent change in NAC for individual i, defined as (pre-NAC – post-NAC)/pre-NAC,

$\%E_i$ is savings of the total measure bundle that participant i received (estimated by the engineering model) as a percent of typical energy consumption,

T is a treatment indicator variable, which is 1 if i is a participant or 0 otherwise

In this model, the coefficient associated with total engineering percent savings estimate, γ, is an adjustment factor of these savings and the treatment dummy coefficient, β, is an estimate of the constant percent change in NAC across customers with any measure bundle.

Total savings for the home receiving a given measure bundle is given by:

$$S_i = (\hat{\beta} + \hat{\gamma}\%E) * PreNAC_i$$

These estimated savings are converted into measure savings for each participant i based on the relative engineering savings proportions of each measure for that participant. Total measure savings are averages of the measure savings across all participants receiving the measure.

3.2.3 eQUEST engineering modeling

We based our measure models on engineering simulated values rather than tracking measure savings in order to use the most consistent and accurate dwelling type and climate zone-level estimates of savings as a percent of baseline consumption. The more accurate the relative savings across measure bundle savings and climate zones, the more effectively the adjustment parameter of the model will scale the measure savings.

To develop simulated savings estimates by building type and climate zone for each of the residential HVAC measures under evaluation in PY2020, we calibrated DEER prototypes in eQUEST using:

- the pre-participation energy consumption profile of participants
- data for nonprogrammable thermostats from RASS for baseline thermostat schedules
- adjustments of lighting and plug load density.

The calibrated consumption values served as the base case in simulations used to estimate energy efficiency from the installation of the various efficient end uses. We used the best data available from workpapers, studies, and previous evaluation findings as inputs in the simulations used to estimate the impact of the residential HVAC measures under study. The sources of the inputs used include:

- for smart thermostats – setpoints/degrees of setback so that cooling and heating savings are 2% to 3%, in line with PA workpaper estimates

- for fan motor replacements – supply kW (0.00065 to 0.0004 kW/cfm) and delta-T adjustments (2.054 F to 1.012 F) based on the 2018 HVAC evaluation
- for fan controls – cooling EIR adjustment (efficient EIR = 0.88428 * baseline EIR) from deemed WP WPSDGEREHC0024_R3_Res Fan Delay Controller that is based on an SCE study, adjusted to reflect claimed kWh savings reported in the PY2020 tracking data
- for duct testing and sealing – duct air loss reduction (from 38.5% to 15% for MFM from and 33.7% to 15% for SFM/DMO) from deemed WP, SWSV001-01, adjusted to reflect claimed kWh and therm savings reported in the PY2020 tracking data

Once the best available simulation inputs were established, we simulated every combination of measures that occurred in the population. For instance, some households received duct testing and sealing and fan control measures; others received only duct testing and sealing. Still others received other measure combinations. For each measure and combination of measures, we ran a "last-in" simulation to determine the individual measure or combination of measure savings. For installed measures where engineering simulation estimates were not developed (faucet aerators and showerheads), we used tracking savings in the measure models.

3.3 Load shapes

Hourly load and savings shapes estimates provide an understanding of when energy savings (in kW) occur from programs and measures customers install. Such estimates allow the identification of load variation on an 8,760 or average hourly basis. Understanding when savings occur can potentially inform program improvement, determine peak-period impacts for any definition of peak, and indicate the extent to which program energy savings can be used as a resource.

DNV estimated hourly load and savings shapes for homes that received residential HVAC measures through direct install programs using site-level (weather normalization) regression models and an hourly DID method. The site-level hourly regression models we estimated were based on pre- and post-program hourly data and take the following form:

$$Y_{ijh} = \alpha_{ish} + \beta^{H}_{ish} H_{ij} + \beta^{C}_{ish} C_{ij} + \varepsilon_{ijh}$$

Y_{ijh} = consumption for a given customer i for day j and hour h

H_{ij}, C_{ij} = customer-specific heating and cooling degree days for day j from a specified base determined using daily models

α_{ish} = customer-specific baseload for hour h and season s

β^{C}_{ish}, β^{H}_{ish} = customer-specific cooling and heating trends for hour h and season s as a function of degree days

Using model results, hourly estimates of consumption in the pre- and post-program period were generated based on the following formula:

$$\hat{Y}_{ijh} = \hat{\alpha}_{ish} + \hat{\beta}^{H}_{ish} \dddot{H}_{ij} + \hat{\beta}^{C}_{ish} \dddot{C}_{ij}$$

$\hat{Y}_{ijh}$ = estimated consumption for a given customer i for day j and hour h

$\dddot{H}_{ij}$, $\dddot{C}_{ij}$ = HDD and CDD based on TMY/CZ2020 and the selected base used in the regression.

We applied this approach to a full year of hourly data using data from both participant and comparison group (non-participant) households and provided predictions of consumption for all hours of the year based on TMY/CZ2020 weather data.

We then used predicted consumption for all hours from the pre- and post-period in a DID framework to produce an hourly load savings shape. We fit the DID model using the methodology as published in Chapter 17, section 4.4.5 of the Uniform Methods Project.[37] Estimated hourly savings load shape is given by:

$$\Delta Y_{jh} = \left(\hat{Y}_{jh}^{part,pre} - \hat{Y}_{jh}^{part,post}\right) - \left(\hat{Y}_{jh}^{np,pre} - \hat{Y}_{jh}^{np,post}\right)$$

ΔY_{jh} = treatment effect for hour *h* in day *j*

$\hat{Y}_{jh}^{part,pre}$ = the average load across participants in the pre-period for hour *h* in day *j*

$\hat{Y}_{jh}^{part,post}$ = the average load across participants in the post-period for hour *h* in day *j*

$\hat{Y}_{jh}^{np,pre}$ = the average load across non-participants in the pre-period for hour *h* in day *j*

$\hat{Y}_{jh}^{np,post}$ = the average load across non-participants in the post-period for hour *h* in day *j*

The estimated hourly DID estimates in this case have substantial noise; a limitation overcome by using average hourly loads rather than annual 8,760 individual hour loads.

3.4 Program attribution

This study also examined PA program influence on residential HVAC measure installations to understand what percentage of the installations would have occurred in the absence of the program. Participants that would have installed the same measures in the absence of the program are called free-riders. They are referred to as free-riders because they are receiving incentives from programs for actions they would have taken without the programs' existence. Gross measure savings estimate change in energy use due to program participation, regardless of why customers participated, while net measure savings estimate change in energy use without free-riders.

DNV developed estimates of the ratio of net to gross savings (the net-to-gross ratio or NTGR) to estimate net savings. A NTGR equal to 1.0 indicates that PA-sponsored programs influenced every single smart thermostat installation—none of the program-tracked installations would have occurred in the absence of the program. The difference between the NTGR and 1.0 is the free-ridership proportion; for example, 25% free-ridership would yield a ratio of 0.75, meaning 75 percent of the installations were attributable to the program and would not have occurred in the absence of the program.

DNV surveyed participants who were decision makers for single-family and mobile home program installations, and participating property managers who were decision makers for direct install programs targeting multifamily. From the survey responses, DNV calculated the level of free-ridership and its complement, the proportion of program installations that could be attributed to the program.

DNV's approach focuses on assessing three 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 savings depends on the number of measures installed (quantity), the efficiency of the measures (efficiency), and the duration that the measures are installed (timing).

DNV's method of calculating NTGRs assess three dimensions of free-ridership: timing, efficiency (when applicable to the measure), and (for multifamily property managers) quantity. The timing question asks how soon the measure would have been installed absent the program. The program gets full attribution for any measure that would not otherwise have been installed at all, and it gets partial credit for accelerating the timing compared to when respondents say they would have been installed the measure absent the program. The efficiency question applies to smart thermostats and fan motors. It gives the program full credit for the measure if the respondent indicates they would have installed nothing or a standard efficiency

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

measure in lieu of the program measure. The quantity question asks how many units would have been installed absent the program. This question is applicable to property managers who approved installation of multiple thermostats, but not to single-family and mobile home occupants, who were limited by the programs to a single installation of each measure type per home. Section 5.2.1 presents program attribution estimates for the residential HVAC measure evaluation.

4 COMPARISON GROUP ASSESSMENT

The PAs provided account level data on household characteristics including household composition by age, household size, home ownership, and income for participants and matched non-participants. These data represent a combination of data drawn from the PA customer information systems and third-party customer data acquired by the PAs. The table below summarizes the number of customers for which data was requested by DNV and received from the PAs. The data received provided coverage for over 80% of participant and matched non-participant customer accounts (Table 4-1).

Table 4-1. Summary of account level demographic data provided by the PAs, PY2020

PA	Data requested	Data provided	% Data provided
PG&E	446,351	360,335	81%
SCE	185,237	172,448	93%
SCG	397,568	393,814	99%
SDG&E	127,505	117,245	92%

We assessed balance from matching using load markers, tenure, and the following household demographic characteristics provided by the PAs:

- **Presence of seniors and children in the household.** Households with seniors above 65 years of age and children under 5 years of age have a higher probability of occupants during the day which in turn impacts energy consumption and savings achieved.
- **Household size.** Energy consumption is directly proportional to the number of occupants in the household.
- **Home ownership.** Homeowners have more agency and are decision makers who are able to undertake energy efficiency upgrades in their homes.
- **Income.** Income is an important factor that influences customer ability to participate in programs and is highly correlated with education and the ability to navigate program and technology related information.

A comparison of the distributions of these household characteristics for participants and their matched non-participants shows good correspondence between the two groups and indicates that the selected non-participants provide a solid basis for controlling the effect of program exogenous changes on household energy consumption. Below are summary distribution charts for household composition (Figure 4-1) and household size (Figure 4-2). Additional charts that compare the distribution of participants and their matched non-participant counterparts by home ownership and income are included in Appendix .

Figure 4-1. Comparison group assessment by household composition, PY2020

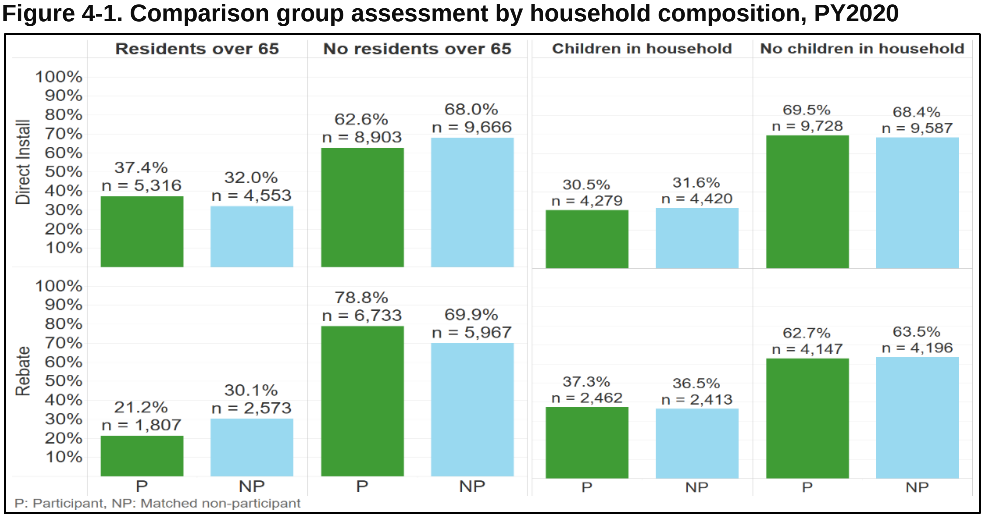
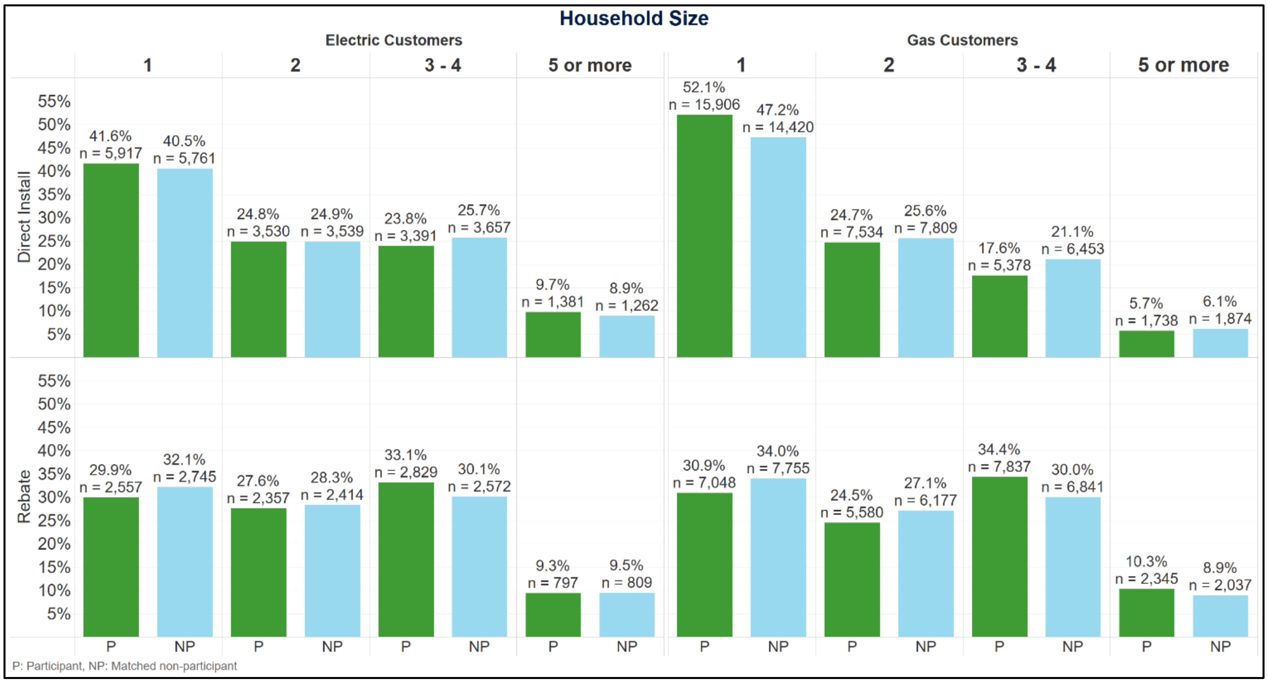


Figure 4-2. Comparison group assessment by household size for electric and gas customers, PY2020



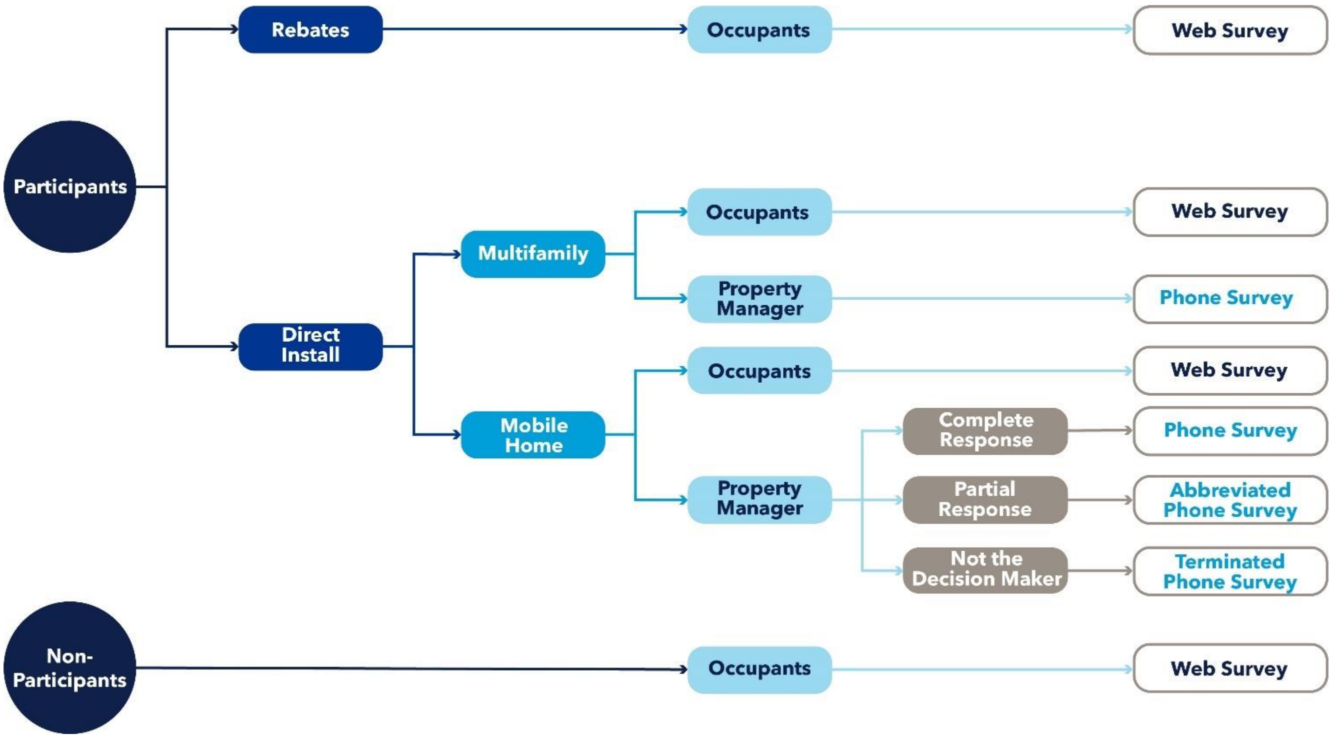
5 SURVEY RESULTS

5.1 Survey approach

DNV surveyed PY2020 rebate and direct install program participants (occupants and property managers) and non-participants (occupants who did not participate in the programs). The primary survey objective was to develop estimates of free-ridership. The survey data also allowed us to identify and understand the influence of exogenous factors such as COVID-19 and changes in energy use behavior on program savings.

The non-participant survey served as a point of comparison with respect to thermostat use and any self-reported changes in the household that are separate from the program. Non-participants were selected as a random sample from the matched comparison group for direct install and rebate programs. DNV also conducted surveys among property managers who are the decision makers for installations in the case of direct install programs that serve multifamily. Figure 5-1 summarizes the data collection approach for the PY2020 residential HVAC evaluation.

Figure 5-1. Survey Data collection approach for residential HVAC evaluation, PY2020



Topics covered by the participant, non-participant, and property manager surveys are summarized below in Table 5-1. The complete surveys are provided in Appendix M.

Table 5-1. Residential HVAC survey topics – participants, non-participants, and property managers, PY2020

Survey Topic	Participants	Matched Non-participants	Property Managers
Free-ridership			
Acquisition/installation year	•	•	•
Free-ridership questions – smart thermostat, fan motor replacement, fan controls, duct testing and sealing	•		•
Thermostat			
Brand and model of smart thermostat installed	•	•	•
Type of thermostat installed previously in the home	•	•	•
Previous and current smart thermostat use	•	•	•
Comfort post smart thermostat installation	•	•	
Satisfaction with the smart thermostat	•	•	•
Household			
Main heating/cooling system	•	•	
Changes in home: EV, refrigerator, lighting, pool, spa etc.	•	•	
Demand response: Interest, barriers to participation, p	•	•	
Dwelling characteristics: Dwelling type, square footage, building vintage	•	•	•
COVID – 19 impacts on households	•	•	
Demographics: Household size and composition by age, education, primary household language, home ownership, income	•	•	

5.1.1 Survey mode and sample disposition

Participant and non-participant occupant surveys. DNV administered web surveys among participants and matched non-participants over an approximate 10-week period from November 2021 to January 2022. The sample frame for participant surveys were customers who had received rebated or direct install residential HVAC measures in PY2020. The sample frame for non-participant surveys was drawn from the set of matched comparison households used in the consumption data analysis. Matched comparison households are a set of non-participants who have been matched to the participants based on multiple variables including location and energy consumption patterns (see Section 8.5.2).

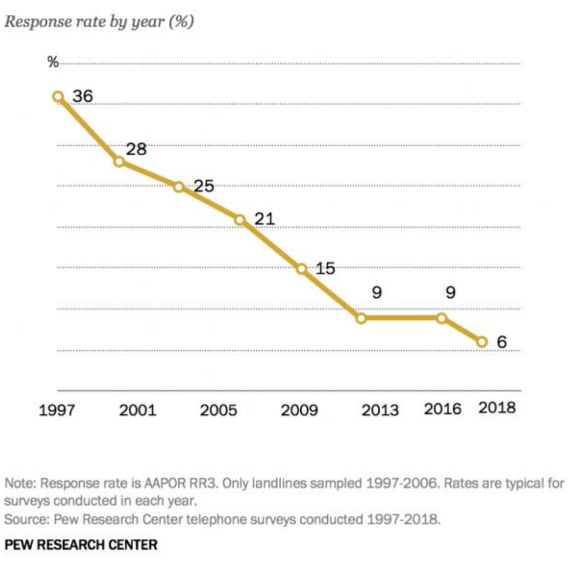
DNV attempted a census approach for the participant occupant surveys and included all customers with available email contact information who were not on the PAs' do-not-contact list in the final survey sample frame. A random sample from the matched comparison households which included customers with email information and not on the PAs' do-not-contact list was drawn for the non-participant survey. Respondents were offered a $300 lottery incentive to complete the survey. Survey invitees were encouraged to complete the survey and two reminders were sent through the survey fielding period.

The surveys included both CPUC and IOU branding to boost occupant 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 5-2.

Table 5-2. Sample disposition for participant and non-participant occupant surveys, PY2020

Occupants (Participants)	TOTAL	PG&E	SCE	SCG	SDG&E
Invites sent	36,459	8,840	6,469	16,339	4,811
Not started	31,269	6,895	5,884	14,476	4,014
Incomplete	792	269	114	316	93
Completed	**3,853**	**1,508**	**440**	**1,346**	**559**
Response rate	**11%**	**17%**	**7%**	**8%**	**12%**
Occupants (Non-Participants)	**TOTAL**	**PG&E**	**SCE**	**SCG**	**SDG&E**
Invites sent	107,425	25,230	29,231	28,836	24,128
Not started	98,653	23,310	27,447	26,799	21,097
Incomplete	2,125	427	465	522	711
Completed	**7,621**	**1,796**	**1597**	**1,935**	**2,293**
Response rate	**7%**	**7%**	**5%**	**7%**	**10%**

Figure 5-2. Pew Research Center telephone survey response rates, 1997-2018



Mode choice and response rates. A US Census report released in April 2021 examines trends in computer and internet use in 2018 and states that among all households in 2018, 92% had at least one type of computer and 85% had a broadband internet subscription. Over 80% of rural households were found to use computing devices and have an internet subscription. While higher rates of connectivity were found in affluent households and those with higher rates of educational attainment, the overall high reach of web surveys ensures that a representative and significant majority of customers are able to receive and respond to a web survey.

DNV has proven to be adept in gathering insights from the California PAs' residential customers and achieving robust sample sizes and response rates, for program participant and general population surveys. Through establishing best practices such as cobranding with the PAs, respondent ability to validate the legitimacy of survey efforts, establishing a trusted IOU domain sender's address for use in the survey invitation, and availability of incentives for eligible respondents who complete the survey, DNV has surpassed response rate benchmarks, such as those achieved by long-running phone surveys conducted by Pew (Figure 5-2).[38]

Property manager surveys. DNV administered a telephone survey for the multifamily direct install program measures where property managers served as the primary point of contact for the program for multifamily buildings. Surveys were fielded for an approximate two-week period in January 2022. The sample frame was constructed from the list of PY2020 properties that received no cost thermostats through direct install programs. Similar to the participant and non-participant surveys described above, DNV offered a $200 lottery style incentive for assistance in completing the survey. The sample disposition for the property manager surveys is summarized below (Table 5-3).

Table 5-3. Sample disposition for property manager surveys, PY2020

Property Managers	TOTAL	PG&E	SCE	SCG	SDG&E
Population	1,238	491	248	410	89
Sample	295	140	67	46	42
Eligible, non-interview	32	17	12	3	0
Unknown eligibility, non-interview	82	52	4	16	10
Not eligible	142	21	43	45	33
Completed	**81**	**64**	**3**	**5**	**9**
Response rate	**27%**	**46%**	**4%**	**11%**	**21%**

The property manager surveys mainly inform program attribution presented previously in Section 5.2.1. Property managers do not have visibility into or knowledge of occupant characteristics or behavior impacting energy use. In the following sections, we present insights related to occupants such changes in the home that may impact energy use, how participants use their smart thermostats, COVID-19 impacts on the household, and demand response participation. These aspects are necessarily only knowable by occupants and hence all survey results presented on these topics are based on the occupant web surveys conducted with participants and their matched non-participant counterparts.

5.1.2 Sample weights

DNV applied sample weights to balance participant (occupants and property managers) and non-participant survey samples to participant population proportions by PA, fuel type, climate zone category, and consumption (kBtu) level. Details of the

[38] https://www.pewresearch.org/fact-tank/2019/02/27/response-rates-in-telephone-surveys-have-resumed-their-decline/

weighting procedure are found in Appendix K. Overall, the primary research conducted for this evaluation had balanced survey samples requiring minor corrections for over and under representation by any strata.

5.2 Survey results

5.2.1 Free-ridership and program attribution

The central objective of the participant surveys was to capture self-reported responses that provide information on free-ridership and allow estimation of NTGRs that were then used to adjust gross savings estimates. This self-reported NTGR approach involved asking program participants a series of questions that were aimed at establishing if the residential HVAC measures would have been installed in the absence of program incentives, and if so, the extent to which the installation timing might have differed in the absence of the program. For property managers of multiple homes, the survey also asked if the program increased the quantity of residential HVAC measures installed.

Program incentives for smart thermostats acquired through rebate programs range from $50 to $75. In the case of the rebate programs, participant surveys with occupants inform free-ridership.

Customers served through direct-install programs receive all the residential HVAC measures for free. Property manager surveys inform free-ridership estimates in the case of direct install programs for multifamily where the property manager is the decision maker for multiple households rather than the occupants in the individual households receiving measure installations. The details of the free-ridership scoring algorithm used are provided in Appendix .

Participant and property manager survey based free-ridership estimates are weighted by electric and gas PA gross savings claims to arrive at final electric and gas program attribution estimates (Figure 5-3). Responses reveal a general pattern of lower levels of free-ridership and higher program attribution of kWh savings for direct install programs relative to rebate programs at approximately 80% or higher for all measures versus just over 45% for smart thermostats acquired through rebate programs. Detailed program attribution scores (NTGRs) by PA, delivery mechanism, and program are included in Appendix .

Figure 5-3. Free-ridership and program attribution scores by delivery mechanism, fuel, and measure, PY2020

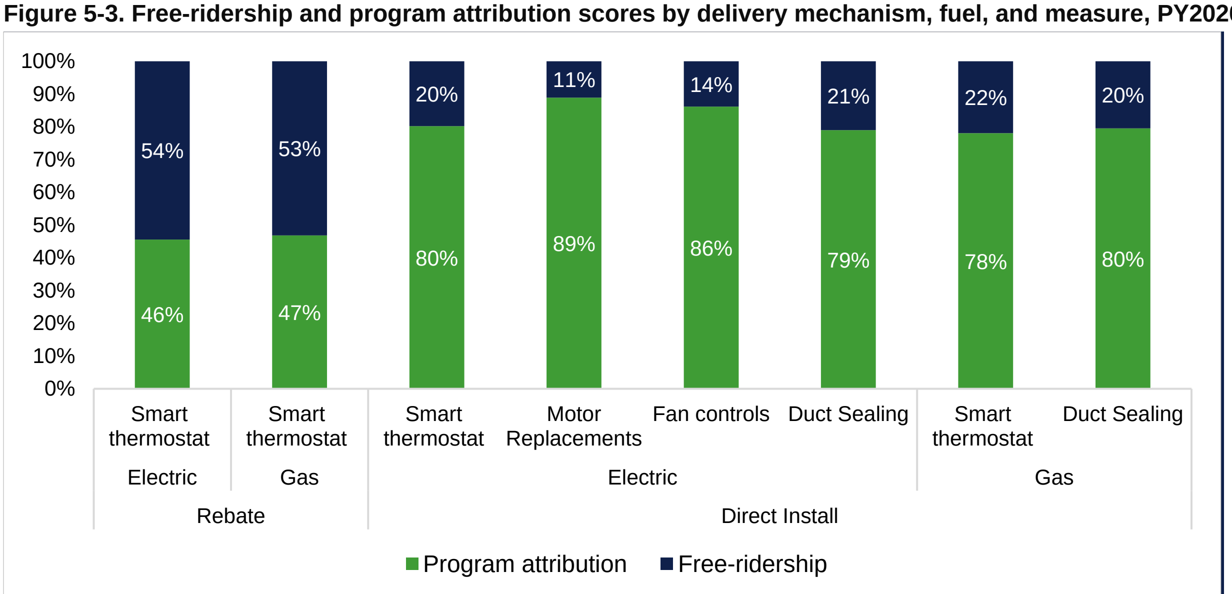


Table 5-4 presents a longitudinal summary of NTGRs by measure and program delivery mechanism which indicates PY2020 evaluated NTGRs values are largely consistent with those from prior impact evaluations.

Table 5-4. Longitudinal summary of NTGRs by program type and measure, PY2018-PY2020

Program type	Measure	Fuel	NTGR		
			PY2018	PY2019	PY2020
Rebate	Smart thermostat	kWh	48%	60%	46%
		kW			
		Therms	48%	51%	47%
Direct Install	Smart thermostat	kWh	89%	94%	80%
		kW			
		Therms	91%	90%	78%
	Motor Replacements	kWh	85%	90%	89%
		kW	82%	91%	89%
		Therms	87%	91%	88%
	Fan controls	kWh		88%	86%
		kW		88%	85%
		Therms		85%	
	Duct Sealing	kWh	94%	95%	79%
		kW	95%	96%	80%
		Therms	95%	94%	80%

5.2.2 COVID-19 impacts

California declared a state of emergency in March 2020 due to the COVID-19 pandemic and went into a lockdown subsequently. The ripple effect of these events was felt by program implementers with direct install program activities coming to a halt and only picking up steam again in the latter half of the year. Customers experienced a sustained impact that continued through the year as disrupted work and school schedules and remote options changed household occupancy and energy use patterns. The pandemic also had a direct impact on employment for customers due to job loss or reduced hours at work and increased uncertainty around household income.

The PY2020 smart thermostat and residential HVAC participant and non-participant surveys included a series of questions that asked respondents about changes in employment status, wages, and household occupancy they may have experienced since the onset of the COVID-19 pandemic in March 2020. Responses to these questions are summarized in Table 5-5. Results indicate that:

- Rebate program participants experienced COVID-19 impacts comparable to their matched non-participant counterparts.
- Direct install program participants experienced significantly higher COVID-19 impacts compared to their matched non-participant counterparts, and rebate program participants and rebate matched non-participants.

All groups had a significant proportion of customers who indicated **energy insecurity**. Energy insecurity is defined as the inability of a household to meet its basic energy needs for heating, cooling, lighting, and other essential end uses. According to results from EIA's most recent Residential Energy Consumption Survey (RECS) published in 2015, one-third of US households reported facing a challenge paying energy bills, one-fifth reported facing a "heat or eat" dilemma where they forewent food and medicine to pay their energy bills, and one-tenth kept their home at an unhealthy or unsafe temperature in order to keep their bills low.[39]

The results from the PY2020 statewide residential HVAC impact evaluation survey have some parallels to the national statistics related to energy insecurity. The "heat or eat" dilemma would have been particularly exacerbated due to the increased occupancy in households due to lockdowns and remote work/schooling for large segments of the population.

[39] https://www.eia.gov/todayinenergy/detail.php?id=37072

Table 5-5. COVID-19 impact on household, PY2020

Group notation[40] / COVID-19 impacts	Non-Participants Matched to Rebate PY2020 (n=4,448)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=3,403)	PY 2020 Direct Install Participants (n=925)
	a	b	c	d
Unemployment by one or more household member	20%[b]	19%[d]	19%	29%[c]
Lost wages by one or more household member	25%[b]	24%[d]	23%	32%[c]
Unable to pay some or full bill in the last year	10%[b]	6%[d]	13%	24%[c]
"Heat or eat" - Forewent basic necessities to pay energy bill in the last year	18%[b]	16%[d]	23%	36%[c]
Kept home at an unsafe/unhealthy temperature in the last year	8%[b]	6%[d]	7%	10%[c]

5.2.3 Changes in home that impact energy use

Respondents were also asked to indicate whether they had made any changes in their home since 2019. 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 either increase or decrease energy use. For example: When asked 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.

Net increase in energy use is estimated 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. Comparison of participant and non-participant average net increase in energy use from these actions is presented in Table 5-6. Negative percentages reflect answers that indicate a reduction in energy use. For example, the negative percentage for "Using more lighting" indicates that among direct-install non-participants, 7% more people said they were decreasing their lighting use than increasing it.

Table 5-6. Changes in home impacting energy use, PY2020

Net Energy Use Increasing Actions	Non-Participants Matched to Rebate PY2020 (n=4,448)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=3,403)	PY 2020 Direct Install Participants (n=925)
	a	b	c	d
Added electric vehicle charging to the home	3%[b]	9%[d]	2%	1%[c]
Using an additional refrigerator	6%[b]	8%[d]	4%	2%[c]
Household size increased	-1%[b]	4%[d]	-2%	1%[c]
Increased living area/square footage of your home	0%[b]	4%[d]	0%	1%[c]
Added a pool/pool pump	0%[b]	1%[d]	-1%	1%[c]
Added a spa	-1%[b]	-1%[d]	-2%	1%[c]
Using more lighting	-3%[b]	6%[d]	-7%	2%[c]
Note: 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.				

A significantly[41] higher proportion of rebate participants compared to their matched non-participant counterparts reported undertaking actions that on balance[42] could contribute to greater energy consumption. For example:

[40] Significant differences in reported statistics between pairs of columns are denoted by superscripts as follows: rebate non-participants versus rebate participants – b, direct install non-participants versus direct install participants – c, rebate participants versus direct install participants– d

[41] Results noted as significant are statistically significant at the 90% confidence and 10% precision level.

[42] The term "on balance" reflects that while there were those that took actions that decreased energy consumption, there were greater number of customers undertaking actions that increased energy consumption. While these differences may be small and the actions undertaken have counteracting effects in some cases, the maximum cumulative impact of these changes is considered here. As noted in section 5.1.3, these differences are expected to have a relatively small effect on whole-home savings.

- Rebate participants, the majority of whom are single-family residents, reported **adding EV charging** to the home in greater proportions than their matched non-participant counterparts at 9% versus 3%.
- Rebate participants reported **using more lighting** than their matched non-participant counterparts at 6% versus -3%.

This difference could reduce energy savings in the basic DID consumption analysis. However, the trend adjustment applied with that analysis, presented in Section 3.2.1.1, corrects for such differences.

There was not a consistent direction to the changes reported by direct install participants and their matched non-participant counterparts. Furthermore, the consumption data analysis does not support non-program related increase among direct install participants relative to non-participants. Hence, for the direct install program, we do not have a similar trend adjustment.

5.2.4 Smart thermostat non-participant and participant user profile

Around 20% of all non-participants indicated that they had a smart thermostat. Of these, roughly half installed their thermostat during the evaluation timeframe, which could potentially lower the savings estimates produced using consumption data analysis with matched comparison groups. Given the trend differential adjustment for rebate programs, only evaluated gross savings estimates for direct install smart thermostats include an upward adjustment for installations of smart thermostats among non-participants over the program period, as described in Appendix G, Section 8.7.3.

DNV contrasted previous and current thermostat use habits of participants and non-participants who acquired a smart thermostat on their own. Rebate program participants report change in thermostat use habits that are in the direction favorable for savings. On balance, these participants report switching off their thermostats when needed less. Direct install program participants report changes in the opposite direction, suggesting either lower engagement with thermostat setback features or a move towards greater comfort (Table 5-7).

Table 5-7. Comparison of previous thermostat and current smart thermostat use, PY2020

Characteristic	Non-Participants Matched to Rebate PY2020 (n=886)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=708)	PY 2020 Direct Install Participants (n=821[43])
	a	b	c	d
Previous Thermostat Use				
Thermostat is switched off when away from home during the day	34% b	42% d	29% d	53%
Thermostat is switched off when asleep/overnight	18% b	22% d	14% d	28%
Smart Thermostat Use				
Thermostat is switched off when away from home during the day	30% b	45% d	29% d	47%
Thermostat is switched off when asleep/overnight	15% b	18% d	10% d	21%

A comparison of direct install and rebate program participants and non-participants who installed their own smart thermostats on how they use the features of their new smart thermostat is summarized in Table 5-8.

As expected, and consistent with results from the PY2019 smart thermostat evaluation, those who bought smart thermostats themselves, either through rebate programs or outside of PA programs, were more inclined to do something proactive with the device than those who received smart thermostats through direct install programs.

[43] Participant survey base reduces to n=821 form n=925 as some respondents may have received other residential HVAC measures but not smart thermostats.

- While a sizable proportion of rebate and direct install program participants reported using their mobile app to access their smart thermostats at 75% and 45%, respectively, this is significantly lower than the 89% of their matched non-participant counterparts who reported doing so.
- While use of other features like auto-away, remote adjustment of temperature using the smart thermostat app, pre-heating and pre-cooling, and using the thermostat fan to schedule HVAC use are not materially different for rebate program participants and their matched non-participant counterparts, direct install program participants uniformly report lower use of these smart thermostat features compared to their matched non-participant counterparts. Relatively lower use of these features reduces the opportunity for savings. For example, the auto-away feature adjusts temperature setpoints when the smart thermostat sensor does not register activity thus delivering savings.

In general, customers receiving a free thermostat through direct install programs report less engagement with the device, indicating an opportunity for improved education on how to use the device for greater benefits.

Finally, both rebate and direct install program participants reported greater comfort in the home with their current smart thermostat than with their previous thermostat. While this could be indicative of takeback,[44] additional data on thermostat setpoint changes are required to verify this.

Table 5-8. Smart thermostat non-participant and participant user profile, PY2020

Characteristic	Non-Participants Matched to Rebate PY2020 (n=886)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020, Single Family (n=708)	PY 2020 Direct Install Participants, Single Family (n=821)
	a	b	c	d
Smart Thermostat Use				
Use the mobile app to access smart thermostat	89% [b]	75% [d]	89% [d]	45%
Remotely adjust home temperature using app	74% [b]	68% [d]	70% [d]	39%
Pre-cool or pre-heat home using app	17% [b]	22% [d]	18% [d]	9%
Use auto-away feature*	33% [b]	29% [d]	29% [d]	11%
Use the smart thermostat to schedule the HVAC system fan	14% [b]	14% [d]	10% [d]	5%
Very or somewhat satisfied with smart thermostat	71% [b]	69% [d]	69% [d]	57%
More comfortable with new smart vs previous thermostat	44% [b]	61% [d]	40% [d]	56%

* To setback thermostat when sensor does not register activity

5.2.5 Demand response program participation

The CPUC adopted supply and demand side requirements to ensure adequate electric power to prepare for potential extreme weather in the summers of 2022 and 2023 in its Phase 2 Decision.[45] Demand-side changes adopted included approval of a large thermostat incentive program designed to reduce air-conditioning by a few degrees during emergencies with special protections for low-income customers in CARE/FERA programs. The CPUC also recommended that all residential customers not currently enrolled in existing supply-side DR programs be considered eligible to participate and automatically enrolled in the residential Emergency Load Reduction Program (ELRP).

The participant and non-participant surveys conducted for the PY2020 residential HVAC impact evaluation included questions aimed at gauging respondent interest in participating in DR programs. Respondent interest in participating in DR

44 Per the definition from the Affordability Rulemaking ALJ Ruling, April 12, 2019, for households that utilize energy below the “essential service quantity which is necessary for health, comfort, and safety” because they cannot afford to use more, higher consumption due to takeback is desirable. While this evaluation does not assess whether customers could be characterized as being below essential use, DNV is currently leading the Essential Use Study to define these essential use thresholds for the California PAs and this study is expected to be completed in early 2023. Future residential HVAC impact evaluations can examine measure savings by households whose baseline consumption is determined to be below applicable essential use thresholds and households whose consumption is above the applicable essential use thresholds to gain an understanding of the savings potential of the technology under conditions where essential use needs are met.

45 https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M427/K639/427639152.PDF

programs is summarized in Table 5-9. While a relatively low 2% - 14% of rebate and direct install program participants and their matched non-participant counterparts indicated that they were already enrolled in a DR program, over half of those not currently enrolled in a DR program expressed some level of interest[46] in participating in a DR program.

Respondents who expressed some level of interest in DR programs or were current participants received an explanation of the benefits of DR programs. Benefits described for participation in a DR program included contributing to electric grid reliability, energy savings through lower energy use, and financial incentives. The description also stated that participants in DR programs always had complete control of their thermostats and could choose to override any adjustments to suit their comfort needs.

In response to their preferred DR program participation pathway, around 33% to 47% of rebate and direct install participants and matched non-participants indicated that they would stay in the DR program and override any adjustments to their thermostats to suit their needs, while a sizable 18% to 28% indicated that would stay in the program and allow the program to automatically adjust their thermostat setpoints. This latter segment hold promise for the potential of DR programs to achieve peak load reductions among customers that are made aware of the benefits of DR program participation.

The top three barriers to DR program participation among those who stated that they would not participate in DR programs and would opt-out if auto-enrolled are concerns related to privacy and security when allowing access to household appliances, concerns that program participation will compromise the comfort of their home, and lack of awareness about DR programs. There are no material differences along these barriers between rebate and direct install program participants and their matched non-participant counterparts suggesting that a broad education and outreach campaign that cuts across various segments could be effective.

Table 5-9. Customer interest in DR programs, PY2020

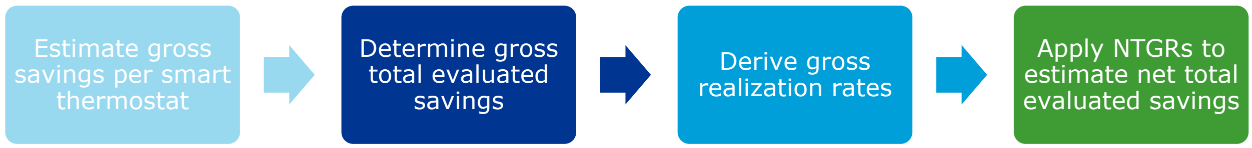
Demand Response	Non-Participants Matched to Rebate PY2020 (n=4,448)	PY 2020 Rebate Participants (n=2,928)	Non-Participants Matched to Direct Install PY2020 (n=3,403)	PY 2020 Direct Install Participants (n=925)
	a	b	c	d
Already enrolled in demand response	2%[b]	14%[d]	3%[d]	8%
Very interested in demand response	14%[b]	19%[d]	14%[d]	13%
Neutral to very interested in demand response	56%[b]	58%[d]	53%[d]	50%
Neutral to very interested or already enrolled in demand response	58%[b]	73%[d]	55%[d]	58%
Preferred pathway to participation among those already enrolled and those with some level of interest in DR programs				
	(n=2,653)	(n=2,120)	(n=1,987)	(n=534)
Would stay in program and during program events, would allow the program to automatically adjust thermostat set points	18%[b]	28%[d]	20%[d]	22%
Would stay in the program, and during program events, would override any adjustments, if it was inconvenient	39%[b]	47%[d]	37%[d]	33%
Would not agree to participate and would opt-out of the program if auto-enrolled	11%[b]	10%[d]	9%[d]	14%
Barriers to participation among those who would opt-out if auto-enrolled in DR programs				
	(n=283)	(n=219)	(n=207)	(n=70)
Would not let anyone access their household appliances or data due to privacy and security concerns	51%[b]	52%[d]	53%[d]	39%
Concerns that program will compromise comfort of their home	32%	33%[d]	32%[d]	45%
Don't know enough about it	25%[b]	27%	27%	29%
Do not use a lot of heating/cooling in the home	17%[b]	15%[d]	20%[d]	10%
Insufficient incentives	8%[b]	22%[d]	11%[d]	15%
Too complicated	5%[b]	14%[d]	4%[d]	10%
Currently not satisfied with the utility and therefore would not consider this	3%	4%	3%	5%

[46] Respondents who rated their level of interest on a five-point interest scale as 3 – 5 (Neutral to Very Interested)

6 IMPACT RESULTS

This section presents estimated electric (kWh) and gas (therm) savings from residential HVAC measure installations by housing type and climate zone. Separate estimates are provided for measures delivered by direct install and rebate programs. Savings estimates per unit are used together with tracked installation counts to generate gross evaluated savings and gross realization rates by PA and statewide. Net evaluated savings for each PA are estimated by applying NTGRs to gross evaluated savings (Figure 6-1).

Figure 6-1. Impact evaluation approach

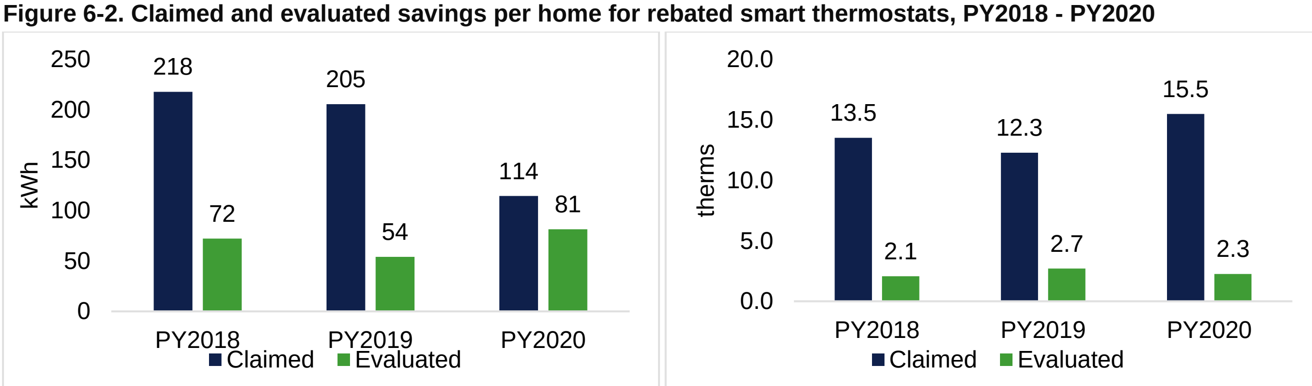


6.1 Rebate whole-home savings

We estimated whole-home savings for sites where only smart thermostats were installed. These represent savings estimates for the rebated smart thermostats. The tracking data indicates that a majority of homes that received smart thermostats through rebate programs installed only this measure. In addition, a large majority (97%) of rebate program smart thermostats were installed in single family homes.

Figure 6-2 provides estimates of smart thermostat savings per home delivered through rebate programs from the PY2020, as well as results from the PY2018 and PY2019 evaluations. Evaluated savings are presented along with claimed savings from the tracking data. In PY2020, on average, smart thermostats saved 81 kWh and 2.3 therms per home.[47] Both the electric and gas savings estimates are statistically significantly different from zero at the 90% confidence level. On average, electric savings are 1% and gas savings are 0.5% of annual consumption.

Figure 6-2. Claimed and evaluated savings per home for rebated smart thermostats, PY2018 - PY2020



In combination with the PY2018 and PY2019 results, the figure indicates evaluated savings across the three program years are lower than claimed. Rebated thermostat electric savings ranged from 54 to 81 kWh per home while gas savings have remained between 2 and 3 therms per home over the three years.

Thermostat optimization, which provides additional incremental energy savings, has become more standard in PY2020. Given this development, we would have expected higher savings in PY2020 than was observed. It is possible that with more

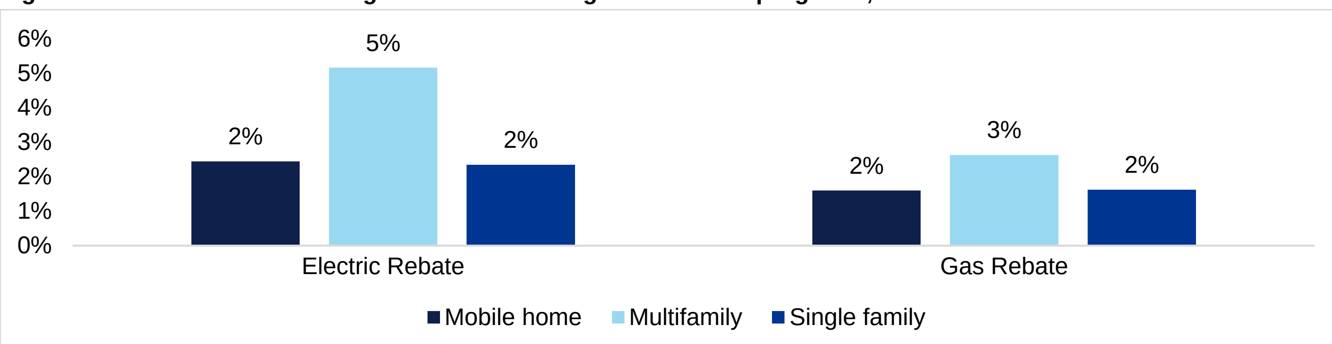
[47] Second stage model results on which these estimates are based are provided in Appendix G. Results include saving estimates' p-values and standard errors, which can be used to assess precision for all estimates. Average annual electric load and its components for rebate program participants are provided in Appendix H.

residential customers spending more time at home due to the pandemic, the optimization feature of the thermostat may have had fewer opportunities for savings through summer setbacks.

The extent and nature of the changes caused by COVID-19 are bigger than a matched comparison group is typically designed to handle. While this introduces additional uncertainty, survey results presented in Table 8-27 indicate that the incidence of key changes associated with COVID-19 were similar between the participants and their matches. Thus, the PY2020 results indicated in Figure 6-2 appear to be reliable for both electricity and gas.

Smart thermostats are designed for efficient energy management of HVAC systems. They target heating and cooling energy consumption and are not expected to affect baseload. Similar to what we observed in the PY2018 evaluation, customers that received rebated smart thermostats in PY2020 appear to have increased baseload more year over year than did their matched counterparts. DID model results for baseload indicate increases in this category of load for rebate smart thermostats participants.. Figure 6-3 provides the percent electric and gas baseload change for customers that participated in rebate programs.[48] Rebate participants have higher energy consumption trends, with an average 2% increase for the single-family homes that are the large majority of the program.

Figure 6-3. Percent electric and gas baseload savings from rebate programs, PY2020



The estimated differential baseline trend for rebate customers suggests some systematic differences between participants and their matched comparison group, unrelated to the smart thermostat. The evaluation adjusted for this differential trend via the methods described in Section 3.2.1. Estimated savings for rebated smart thermostats include this adjustment.

6.2 Direct install whole-home savings

For rebate programs, we were able to estimate savings for a single measure directly from whole-home models. For direct install programs, this approach is not generally possible. In this section, we provide the measures installed through direct install programs and present whole-home savings, which are the basis of disaggregated measure level savings.

Direct install programs offered different mixes of HVAC and other energy efficiency measures. Figure 6-4 provides the percent of households that received measures with electric savings claims by dwelling type. A majority of homes (50% or more) in single family and mobile homes received smart thermostats and fan motor replacements. A majority of single-family homes also received fan controls. The direct install programs did not deliver duct sealing widely, but these were most prevalent in mobile homes.

[48] Model results on which these estimates are based are provided in Appendix G.

Figure 6-4. Percent of homes receiving direct install electric saving measures, PY2020

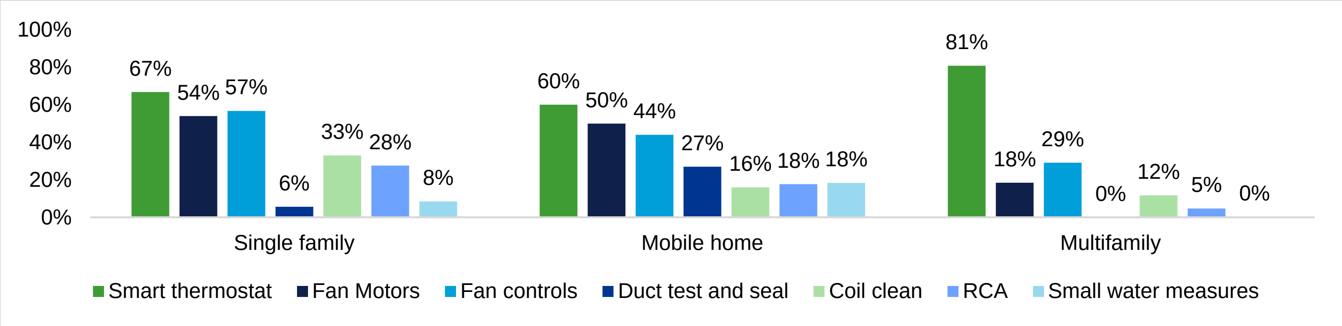
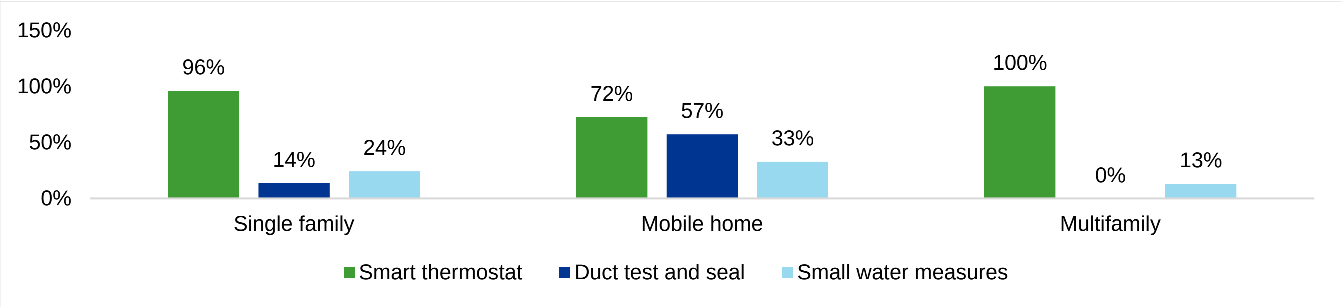


Figure 6-5 provides the percent of households that received measures with gas savings claims by dwelling type. Seventy percent or more of homes in all dwelling types received smart thermostats. A majority of mobile homes also installed duct sealing, while this measure was installed in a limited number of single-family homes. The tracking data indicated negative gas savings for the limited number of sites (less than 15%) that received motor replacements, which were always installed in combination with other measures. We estimated gas savings with and without motors and did not find a significant difference. Since the data indicated little evidence of gas savings penalties, we do not feature motor installations in the figure below and did not consider gas penalties from motors in our evaluated results.

Figure 6-5. Percent of homes receiving direct install gas saving measures, PY2020



While the mix of electric measures installed varied by dwelling type, smart thermostats and motors were installed alone most commonly in multifamily homes (Figure 6-6). These measures were largely installed as part of other bundles in the other dwelling types. Duct sealing was installed alone in about a quarter of mobile homes but was mostly installed in combination with other measures in the other dwelling types. Fan controls were almost never installed alone and overlapped with all other measures including smart thermostats. For gas, smart thermostats were installed alone in the majority of single and multifamily homes, and almost half of mobile homes. Duct sealing was delivered in about a third of mobile homes and a small fraction of single-family homes alone.

Figure 6-6. Percent of direct install measures installed alone and in bundles by dwelling type, PY2020

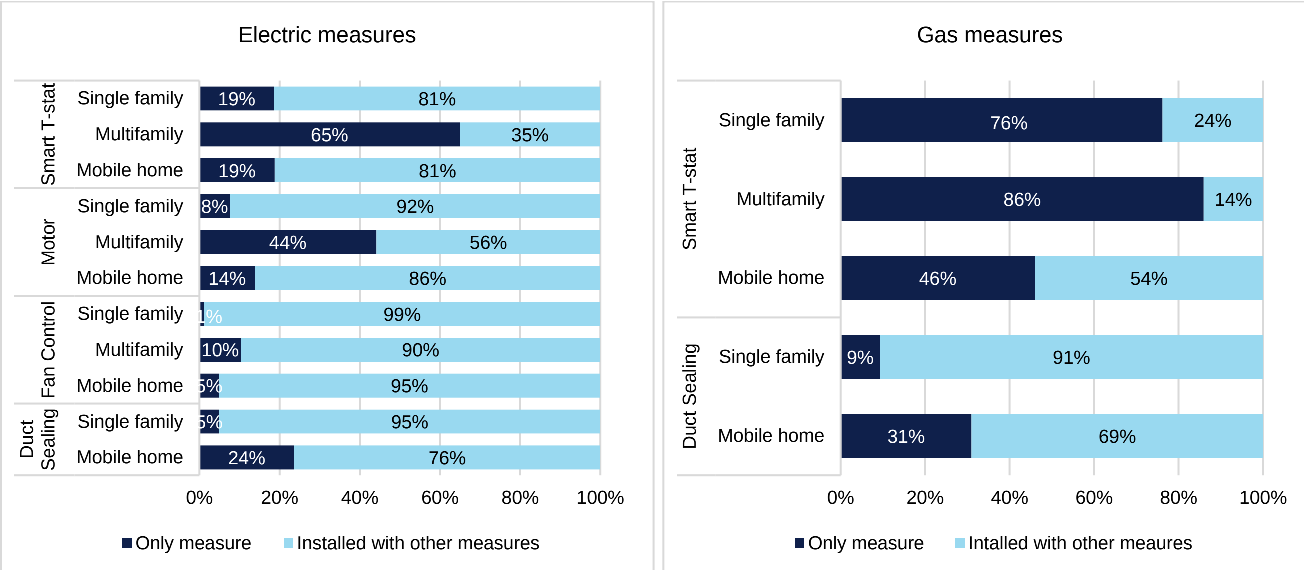


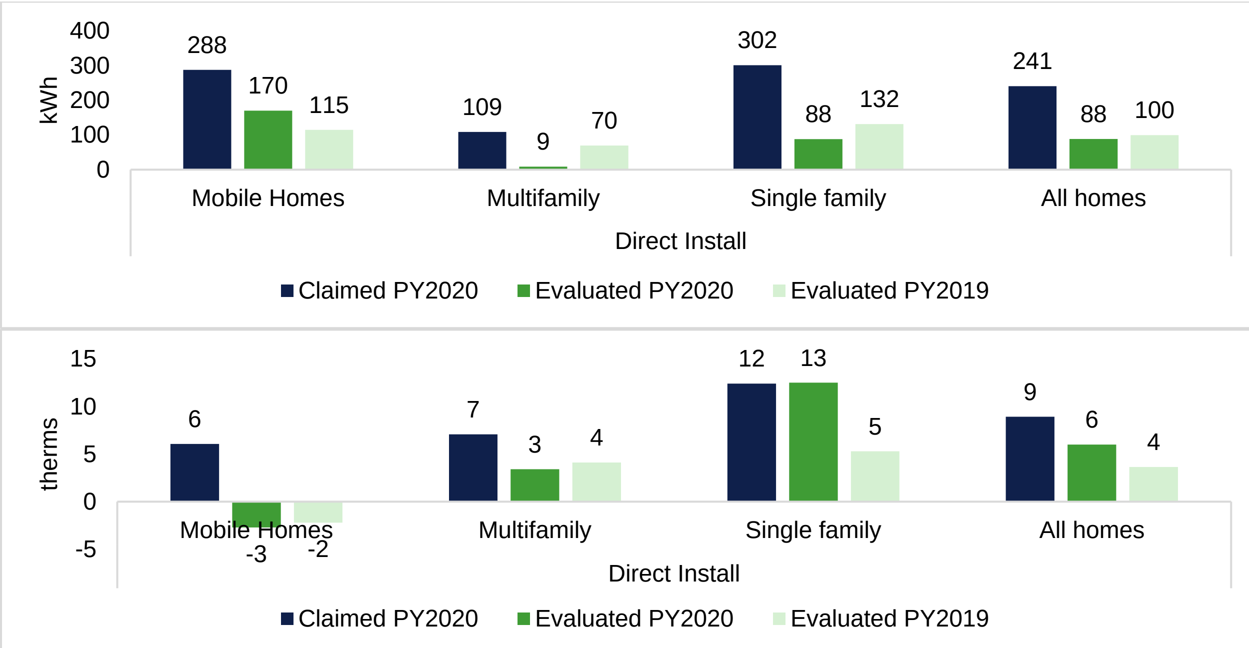
Figure 6-7 provides a PY2020 estimated whole home electric and gas savings compared to claimed savings for direct install programs by dwelling type and across all homes. The Figure also includes evaluated whole-home savings for PY2019 direct install programs for comparison. Whole-home savings are distributed to measures proportional to engineering model savings, as discussed in Section 3.2.2.[49] As described in Section 3.2, our analysis uses change in consumption from pre- to post-installation, with matched comparison groups to control for non-program changes. Looking at all homes, both electric and gas evaluated whole-home savings are of roughly comparable magnitude for PY 2019 and PY2020, and low compared to the claimed savings. There are some differences in the year-to-year comparisons by dwelling type, in part reflecting installation of different measure mixes by dwelling types between the two years. In addition, COVID-19 was in force during the post-installation winter season for all participants and during the post-installation summer season for most participants. In contrast to the findings for the rebate programs, for direct install programs our survey results indicate that participants in all dwelling types and especially multifamily homes had more adverse effects from COVID-19 than their matched non-participant counterparts.[50] How these differences might affect the estimated savings is unclear, but the differences do indicate additional uncertainty not reflected in the standard errors of the estimates.[51]

[49] Details of the PY2020 whole model estimates for direct install programs are provided in Appendix G.

[50] Multifamily participants we surveyed reported higher incidence of job losses and related adverse effects (Table 8-27 in Appendix L), which could have resulted in greater occupancy changes and as a consequence lost opportunities for savings through smart thermostats summer setbacks.

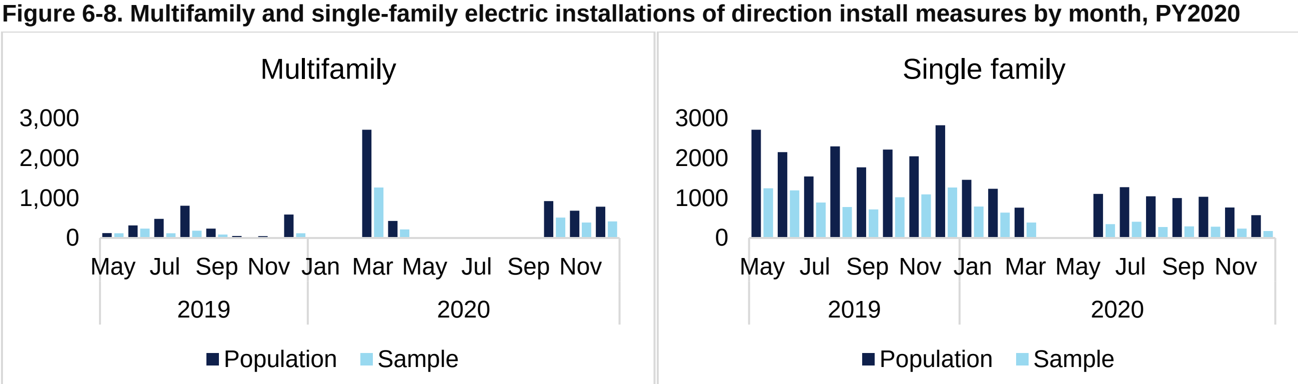
[51] We investigated the possibility of trend differences in energy consumption between direct install participants and their matched comparison homes. Baseload DID model results (presented in Appendix G) provide no evidence of such a trend for direct install participants. Therefore, no adjustments for direct install whole-home savings.

Figure 6-7. Claimed and evaluated whole-home savings for direct install programs, PY2020



In addition, installation patterns of electric measures for multifamily indicate unusual spikes in March 2020 and relatively high installations in April 2020 compared to the rest of the summer months in that year (Figure 6-8). The figure includes installations over time for single-family homes (that are similar to those of mobile homes) to illustrate the unusual installation spike for multifamily homes.[52]

Figure 6-8. Multifamily and single-family electric installations of direction install measures by month, PY2020



6.3 Measure group savings

Whole-home direct install savings are distributed to measures proportional to engineering model savings. Results from the disaggregation of whole homes savings based on engineering estimates are presented in this section. The section also provides results from the engineering simulations that are the basis for the disaggregation.

6.3.1 Engineering estimates

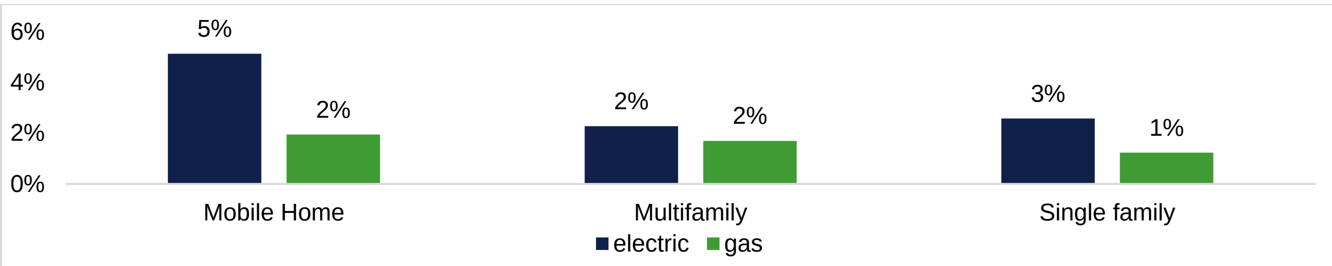
Engineering model savings are derived from a simulation engine that uses prototype models to generate measure savings for different dwelling types, climate zones, and retrofit conditions. The prototypes used to simulate savings were calibrated to

[52] DNV examined the monthly installations by PA and found that PG&E contributed to the March 2020 spike. PG&E clarified that delays in a contract renewal resulted in backlogged work that required the vendor to ramp up its energy efficiency activity.

reflect the pre-installation period consumption profiles of participants. The calibrated electric and gas consumption profiles by dwelling type and climate zone used in the simulations are presented in Appendix N.

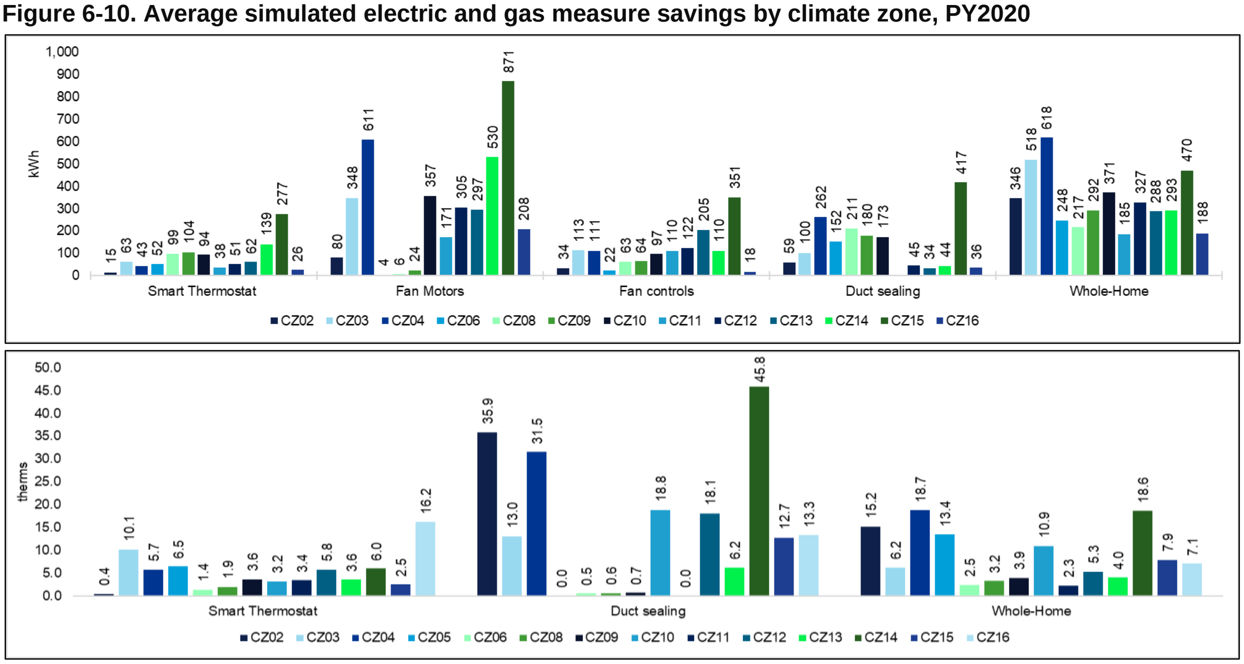
These calibrated values along with the best data available from workpapers, studies, and previous evaluation findings served as inputs in the simulations used to estimate the impact of the residential HVAC measures under study by dwelling type and climate zone. We expressed the sum of the simulated engineering measure savings as a percent of typical consumption provided from the calibration models . Figure 6-9 provides the percent electric and gas simulated savings by dwelling type, which were used in whole-home percent savings models. The values in the figure provide an indication of the level of savings expected from program installations.

Figure 6-9. Simulated electric and gas whole home percent savings by dwelling type, PY2020



The simulated engineering measure savings as percent of the simulated bundle of measures installed at each site were used to allocate the estimated whole-home savings from the consumption data analysis to the individual measures. Allocation is performed at the site level based on the site-level whole-home savings. Figure 6-10 provides the average engineering measure savings estimates by climate zone used to allocate whole-home savings. The values reflect simulation measure savings that vary by climate zone. For example, measures installed in climate zones 13 and 15 have higher simulated savings than those installed in climate zones 2 and 3.

Figure 6-10. Average simulated electric and gas measure savings by climate zone, PY2020



6.3.2 Measure savings estimates

In this section we provide estimates of measure-level savings from direct install programs. Discussion of DID model savings estimates that are the basis of these results is provided in Appendix G.[53]

COVID-19 is a large exogenous shock that could affect participants and matched comparison homes in different ways. While surveys for rebate participants indicate that absence of different outcomes for rebate participants and their matches, there appear to be differential effects on direct install participants compared to their matches, particularly for multifamily participants. We don't know the direction of the effect of these differences, but the differences in COVID-19 related outcomes add uncertainty to estimated savings.

Figure 6-11 provides claimed and evaluated measure-level savings for PY2020 and includes PY2019 values for comparison. Many of the measure-level savings estimates across the two years show similar savings patterns and are lower than claimed.[54] These are likely due to a combination of different mixes of measures between the two years, possible anomalous installation dates, and the additional uncertainties noted above.

Figure 6-11. Comparison of PY2019 and PY2020 claimed and evaluated direct install measure savings per home

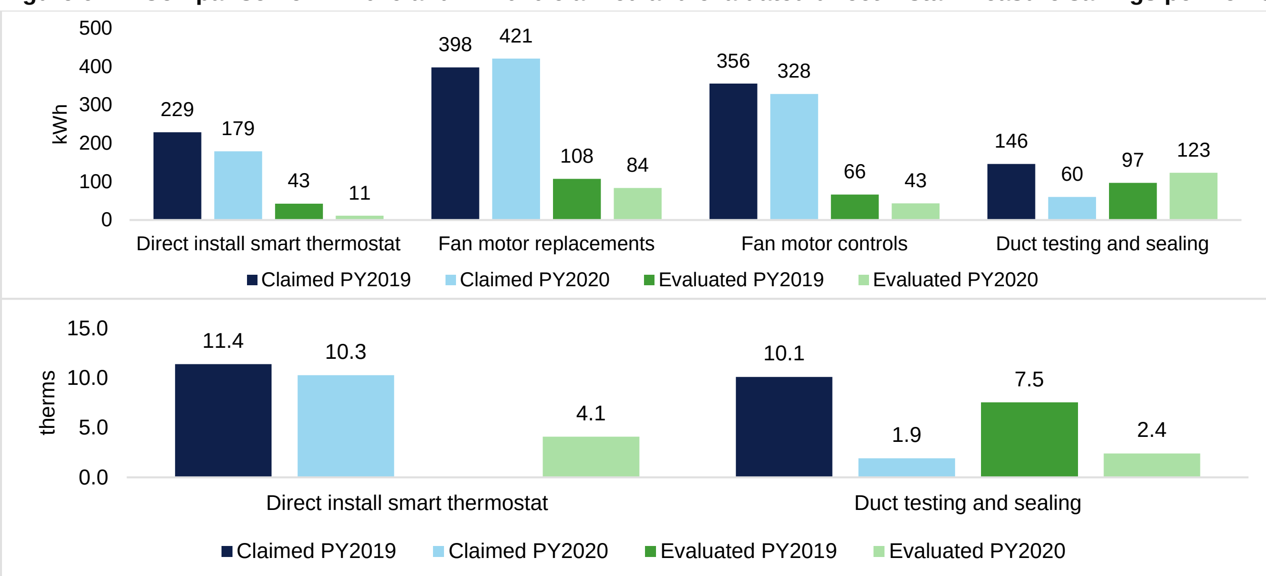


Table 6-1 provides the estimated savings per home along with their standard errors and p values. The table indicates that all measure savings except gas savings for duct testing and sealing are statistically significant and mostly estimated with precision levels of 0.25 or better.

[53] Average annual electric load and its components for direct install program participants are provided in Appendix H.

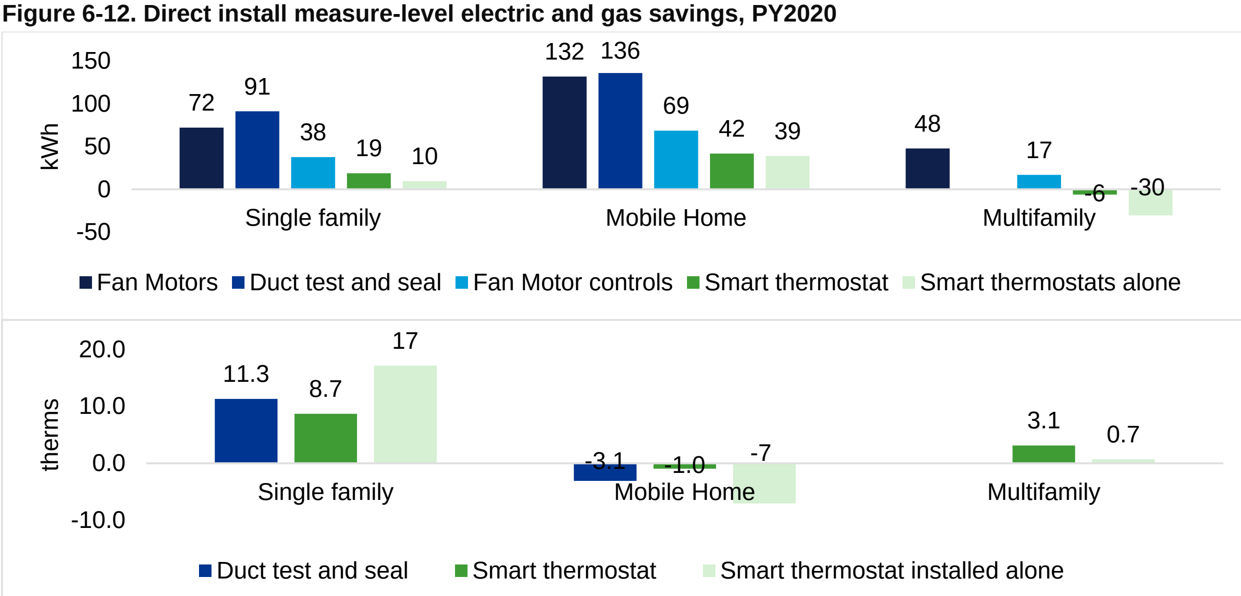
[54] One notable change is the estimated gas savings for smart thermostats in PY2020 compared to PY2019. DNV found no gas savings for smart thermostats in PY2019, while PY2020 gas savings for this measure is, on average, 4 therms per home. In PY2020, by contrast, climate zones 10 and 13 received 27% of the installations each. Since climate zone 13 has greater heating needs than climate zone 10, the additional heating load and the consequent opportunity for heating savings could be one possible reason for the difference between smart thermostat gas savings in the two program years. It is also possible that thermostat optimization, which was not in full effect in PY2019 but became more widely available in PY2020, has contributed to the gas savings observed in the PY2020 evaluation.

Table 6-1. Direct install electric whole-home and measure-level savings models by dwelling type, PY2020

Fuel	Model type	Model estimates			
		savings (kWh)	standard error	Relative precision	p value
Electric	Whole-home	88.0	12.5	0.23	0.00
	Fan motor replacement	83.7	9.8	0.19	0.00
	Fan motor controls	43.3	6.0	0.23	0.00
	Smart thermostats	11.1	4.9	0.73	0.02
	Duct testing and sealing	123.3	12.6	0.17	0.00
Gas	Whole-home	6.0	0.82	0.22	0.00
	Smart thermostats	4.1	0.63	0.25	0.00
	Duct testing and sealing	2.4	1.52	1.04	0.15

We explored the sources of evaluated savings differences across the two program years by examining measure savings estimates by dwelling type. Evaluated savings estimates differences for multifamily homes are the most notable source of the change in PY2020 measure savings relative to PY2019 due to the factors noted above, particularly to possible anomalous installation dates. Electric savings for direct install smart thermostats are lower in PY2020 partly because of the absence of electric savings for multifamily participants in PY2020 (Figure 6-12).[55]..

Figure 6-12. Direct install measure-level electric and gas savings, PY2020



As we discussed in Section 2.1, there are no electric participant IDs with which to evaluate SCG installations. While we lack visibility into electricity consumption for a large number of SCG customers, the dataset used in the PY2020 consumption analysis is of sufficient size to estimate savings, if they were present. Further, PY2020 installations were concentrated in climate zone 13 which has more cooling and heating needs than PY2019 installations which were largely in milder climate zones 6, 8, 9, and 10. Thus, the low PY2020 electric savings for smart thermostats are surprising and counterintuitive. Possible reasons are as stated earlier.

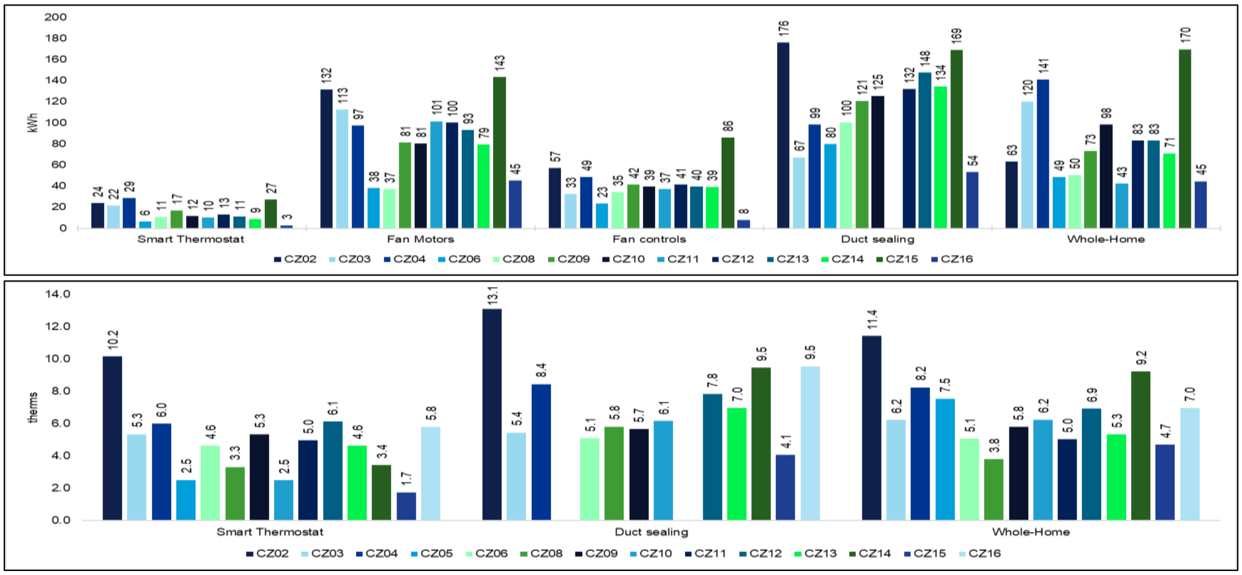
Table 6-2. Claim counts with available electric customer IDs by dwelling type, PY2020

Dwelling type	All measures			Smart thermostat		
	Total	With electric IDs	Percent	Total	With electric IDs	Percent
Mobile home	10,338	7,513	73%	2,368	1,324	56%
Multifamily	22,640	8,201	36%	19,699	5,260	27%
Single family	30,572	27,773	91%	5,875	5,160	88%

55 Second stage model results by dwelling type are provided in Appendix G.

Direct install measure level and whole-home savings by climate zone based on the approach above are provided in Figure 6-13. The two panels in the figure indicate that savings estimates vary by climate zone. The measure disaggregation produces savings nearly proportional to the simulated engineering estimates provided in Figure 6-10. Thus, for example, higher savings are seen in the hot climate zones 13 and 15 for each measure.

Figure 6-13. Direct install whole-home and HVAC measure electric and gas savings by climate zone, PY2020



6.4 Total program savings

We combine measure level estimates with participant counts to calculate total evaluated electric and gas savings. These results along with total savings that can be attributed to the programs (total net savings) are provided in this section.

6.4.1 Electric savings

Table 6-3 provides the number of households with electric service that received an HVAC measure through both direct install and rebate programs, the total gross claimed electric savings, and the total gross evaluated electric savings. Our evaluation found that all measures installed through the program achieved 4.5 GWh of electric savings, which is 27% of expected or claimed savings (gross realization rate). Total gross savings are further adjusted to reflect the portion of savings that can be attributed to program influence. Evaluated net-to-gross ratios (NTGR) exceed claimed values for all direct install measures, as expected, but are lower than claimed for rebated smart thermostats.. Our evaluation indicates that direct install and rebate programs achieved net electric savings of 3.1 GWh statewide.

Table 6-3. Total residential HVAC electric savings, PY2020

Delivery Channel	Program participants	Total Gross Claimed Savings (kWh)	Total Gross Evaluated Savings (kWh)	Gross Realization Rate	Claimed NTGR	Evaluated NTGR	Total Net Evaluated Savings (kWh)
Smart thermostats							
Direct Install Total	29,991	5,365,793	333,102	6%	66%	80%	267,056
Rebate Total	25,129	2,876,022	2,045,931	71%	55%	46%	932,175
Measure Total	55,120	8,241,815	2,379,033	29%	62%	50%	1,199,231
Fan motor replacement							
Direct Install Total	11,601	4,880,184	970,840	20%	66%	89%	863,188
Rebate Total	1	379	84	22%	55%	89%	74
Measure Total	11,602	4,880,564	970,924	20%	66%	89%	863,263
Fan motor controls							

Measure Total	10,246	3,364,350	444,034	13%	68%	86%	382,554
Duct testing and sealing							
Measure Total	6,219	373,222	766,855	205%	66%	79%	605,489
All Measures							
Grand Total	**83,187**	**16,859,951**	**4,560,846**	**27%**	**N/A**	**N/A**	**3,050,536**

*The statewide NTGR is the weighted sum of direct install and rebate NTGRs. The individual NTGRs should be applied to specific programs to roll up to statewide totals.

Table 6-4 provides the number of households with electric measures expected to deliver demand (kW) savings and the total kW savings claimed for them. DNV evaluated demand savings of households that installed the measures with the claimed savings based on peak demand savings estimates during DEER defined peak periods. Households with the measures achieved approximately 774 of gross kW savings, which is 14% of gross claimed savings (gross realization rate). Total gross savings are further adjusted to reflect the portion of savings that can be attributed to program influence. Our evaluation indicates that the direct install programs that delivered measures with claimed demand savings achieved net electric savings of 661 kW statewide.

Table 6-4. Total residential demand savings, PY2020

Delivery Channel	Program participants	Total Gross Claimed Savings (kW)	Total Gross Evaluated Savings (kW)	Gross Realization Rate	Claimed NTGR	Evaluated NTGR	Total Net Evaluated Savings (kW)
Fan motor replacement							
Measure Total	11,601	3,918	381	10%	62%	89%	339
Fan motor controls							
Measure Total	10,246	1,213	163	13%	64%	86%	140
Duct sealing and testing							
Measure Total	6,219	235	230	98%	66%	79%	182
All Measures							
Grand Total	**28,066**	**5,366**	**774**	**14%**	**N/A**	**N/A**	**661**

6.4.2 Gas savings

Table 6-5 provides the number of households with gas service that received the measures through a direct install or rebate program, total claimed gas savings, and total evaluated gas savings. These measures achieved approximately 203,000 therms of gross gas savings, which is 28% of gross claimed savings (gross realization rate). Evaluated NTGR for direct install thermostats and duct sealing are greater than claimed while the NTGR for rebated smart thermostats is lower than claimed at 47% compared to 55%. Our evaluation indicates that direct install and rebate programs caused gas savings of 141,681 therms statewide.

Table 6-5. Total residential HVAC gas savings, PY2020

Delivery Channel	Program participants	Total Gross Claimed Savings (therms)	Total Gross Evaluated Savings (therms)	Gross Realization Rate	Claimed NTGR	Evaluated NTGR	Total Net Evaluated Savings (therms)
Smart thermostats							
Direct Install Total	32,592	334,760	133,472	40%	64%	78%	104,108
Rebate Total	24,182	374,485	54,557	15%	55%	47%	25,642
Measure Total	56,774	709,245	188,029	27%	59%	69%	129,750
Duct testing and sealing							
Measure Total	6,219	11,901	14,914	125%	66%	80%	11,931
All Measures							
Grand Total	**62,993**	**721,146**	**202,943**	**28%**	**N/A**	**N/A**	141,681

6.5 Direct install program load savings Shapes

This section provides summaries of hourly load and savings shapes from homes that installed residential HVAC measure measures offered through direct install programs.[56] The analysis is based on DID estimates using weather normalized hourly (AMI) electricity data.[57]

We provide summaries of whole-home load and savings shapes that reflect the combined effect of all the residential HVAC measures installed by the programs. The multiple measure installations that made the estimation of direct install program annual impacts difficult are also a challenge for hourly savings shapes. Rather than proportionally distribute whole-home savings shapes to individual measures, we also provide savings shapes that rely on the subset of customers who only installed smart thermostats through the direct install programs and homes that installed the other measures without smart thermostats. This choice was motivated by the relatively large number of homes that installed smart thermostats alone. There were not a sufficient number of homes that installed any of the other measures alone to allow a similar analysis. Instead, we provide savings shapes for homes that installed the other HVAC measures but not smart thermostats.

In the following subsections, we first provide average hourly whole-home load shapes before and after measure installations. This is followed by a presentation of average whole-home savings shapes for customers that received direct install residential HVAC measures. Because these savings shapes are based solely on AMI data and not on simulation models, they are informative about when during the day these measures deliver savings. The load and savings shapes are provided by season (summer, winter, and shoulder) as well as across all seasons; the summer season includes data from June through September, winter includes data from December, January, and February, and the shoulder season includes data from the remaining months.

6.5.1 Whole-home hourly load shapes

Figure 6-14 provides weather normalized average hourly electric load shapes for households that installed residential HVAC measures under direct install programs. The plots include shapes for both treatment (solid line) and comparison group (dashed line) households in each panel, with separate rows for pre- and post-installation periods. The average hourly load shapes reflect electricity usage from single family (62%), multifamily (19%) and mobile home (19%) participants and their matches.

The figure indicates that average daily electric load peaks for both groups and all periods at 6 p.m., with highest usage in the summer (June through September) and lowest in the winter (December through February) seasons. The observed peak hours are in line with the updated DEER 2019 peak period definition that covers 4 p.m. to 9 p.m.

The pre-installation average hourly load shapes indicate energy use that is highly similar between treatment and comparison group households in all seasons. The separation in energy use between treatment and comparison group homes in the post-installation period is small and is the basis of hourly savings shapes we present in the next section.

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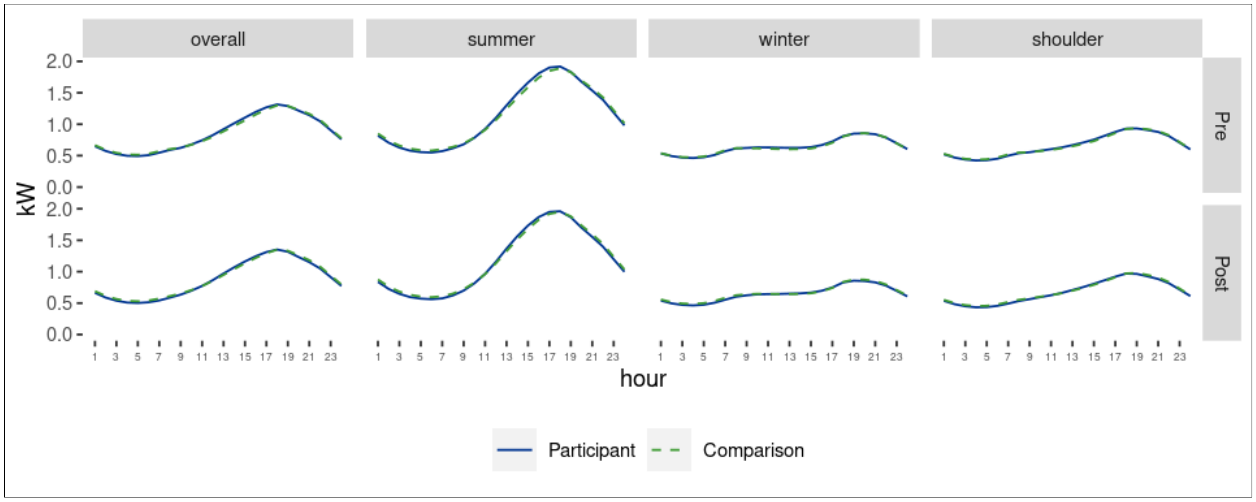
[56] As we indicated in earlier sections of the report, direct install programs offered smart thermostats, fan motor replacements, fan motor controls, duct sealing (evaluated measures) along with other HVAC measure (RCA and coil cleaning) and non-HVAC measures (small water measures such as aerators) that contribute to whole-home savings.

[57] The analysis is based on site-level weather normalization estimates pre-and post-installation. The estimates provide weather normalized hourly load pre-and post-installation for each site, which are averaged and used to estimate hourly savings shapes provided in this section.

Figure 6-14. Average whole-home hourly electric load shapes by season, PY2020



6.5.2 Hourly savings shapes

We calculated DID of weather normalized hourly load to estimate hourly whole-home savings. We produced savings shapes for all dwelling types that installed the direct install residential HVAC measures based on these estimates. The panels in Figure 6-15 provide the average hourly savings by season. These savings shapes represent a combination of all direct install measures. The hours in all figures below are for hour ending; for example, 15 represents the hour that ends at 3 p.m.

Figure 6-15. Direct install whole-home average hourly savings by season for all housing types, PY2020

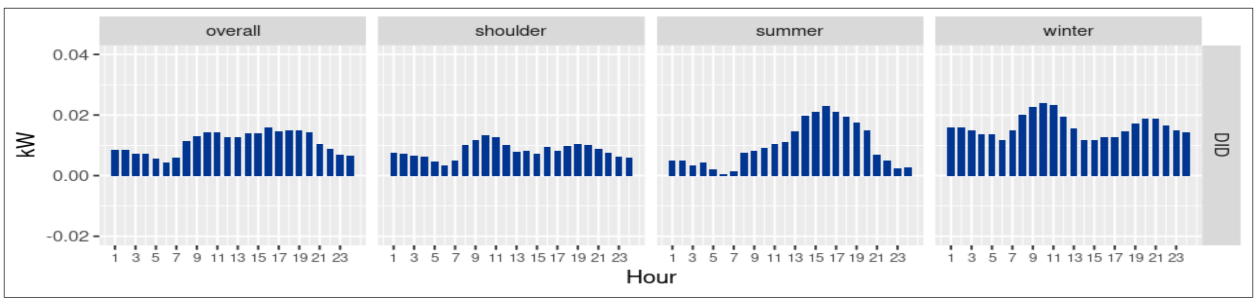


Figure 6-16 provides savings shapes for a subset of homes that installed only smart thermostats. Figure 6-17 provides the savings shapes for homes that installed the other measures but not a smart thermostat (non-smart thermostat savings). The non-thermostat savings clearly drive the overall savings shape. The non-thermostat savings have smooth, well-behaved shapes that are consistent with expectations for energy efficiency measures like fan motors and duct sealing that are expected to reduce consumption proportionally to the end use consumption.

Figure 6-16. Direct install average hourly savings for homes with only smart thermostat installations, PY2020

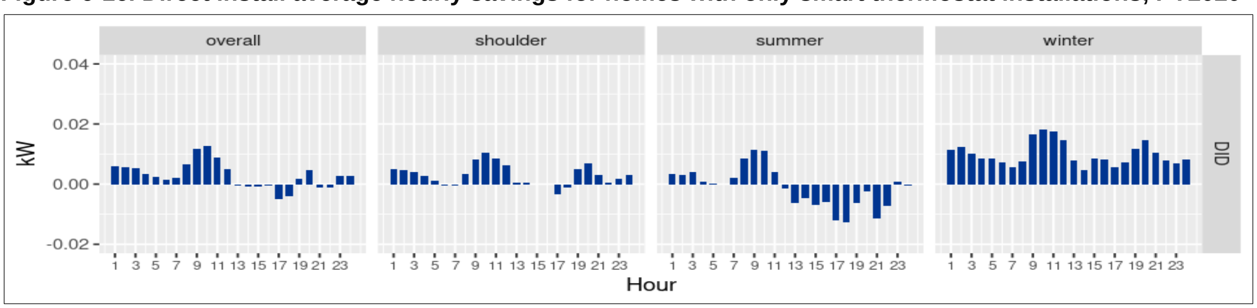
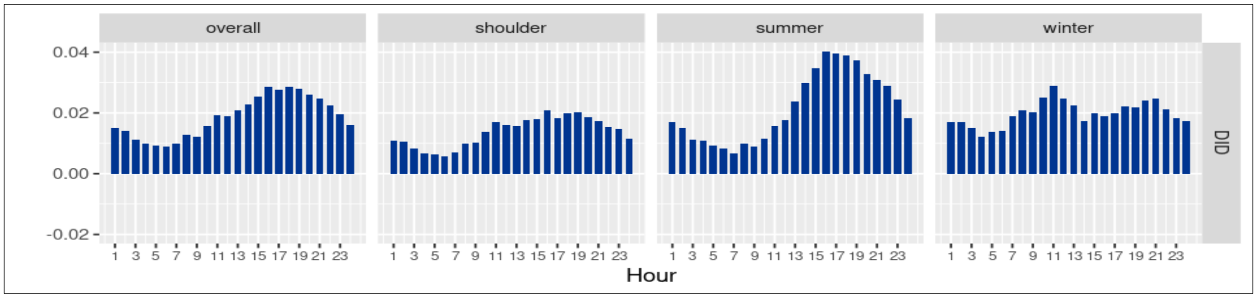


Figure 6-17. Direct install average hourly savings for homes without smart thermostat installations, PY2020



The thermostat savings shapes are much more variable throughout the day and across seasons. These shapes indicate that most savings occur during the shoulder and winter periods. During the summer peak period, thermostats appear to increase the overall system peak rather than lower it. In all seasons, smart thermostats appear to motivate savings more effectively in the late morning hours than during any other time of day. It is challenging to understand effects of the pandemic on savings. Higher levels of working at home could, for instance, undermine the potential for thermostat savings during the day for both heating and cooling periods. This could explain the counterintuitive summer results, but this explanation does not hold for the winter savings shape.

Figure 6-18 through Figure 6-20 provide average hourly savings shapes by season for single family, multifamily and mobile homes that received the direct install measures. There are some notable differences in the hourly savings shapes among the three dwelling types that reflect some combination of dwelling specific heating and cooling dynamics and the different measure mix delivered to each dwelling type. Single family and mobile home installations each have at least 50% of sites installing an efficient fan motor replacement along with many other measures. These measures add up to substantial savings across all seasons for single family and mobile homes. Multifamily installations, in contrast are dominated by smart thermostats. The multifamily savings shape is much more consistent with the thermostat only shape above.

Figure 6-18. Direct install whole-home average hourly savings by season for single family homes, PY2020

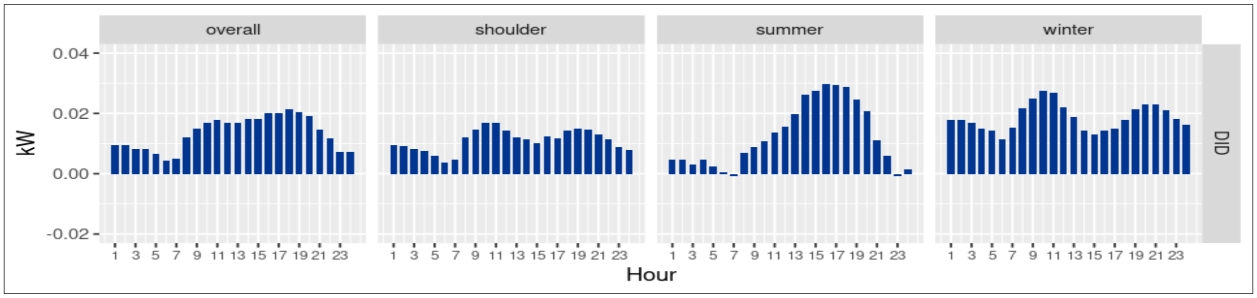


Figure 6-19. Direct install whole-home average hourly savings by season for multifamily homes, PY2020

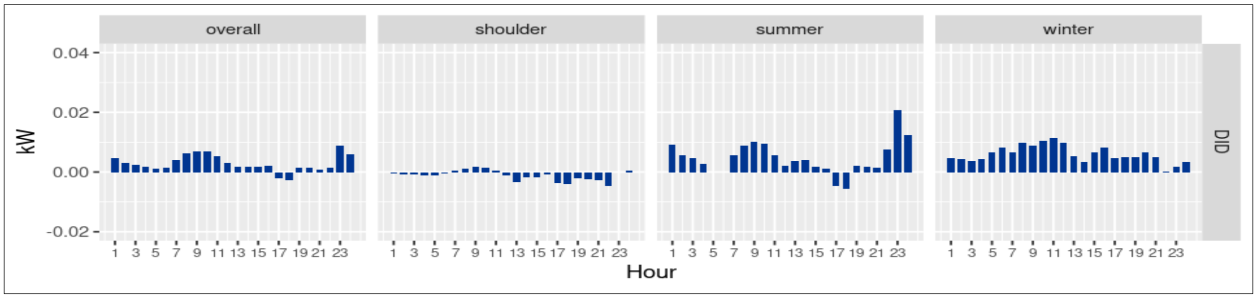
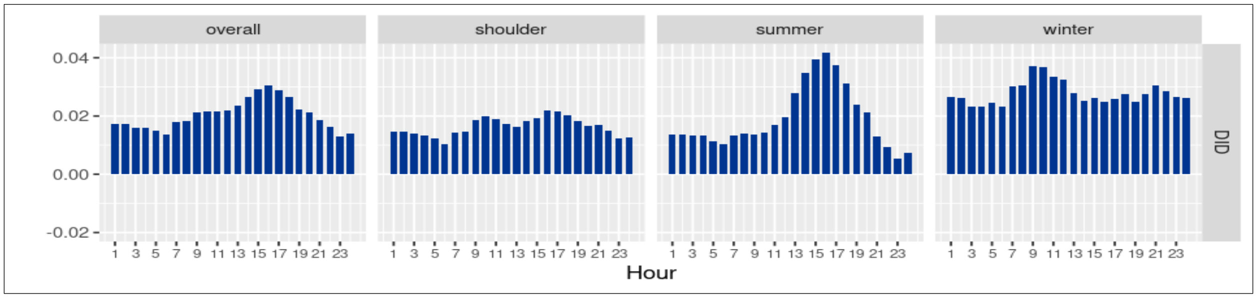


Figure 6-20. Direct install whole-home average hourly savings by season for mobile homes, PY2020



Fan controls continue to be present in the measure mix for this program year and there was some concern that their savings mechanism overlaps with one of the savings capabilities of the smart thermostats. These results seem to indicate that when installed together, the measures did not produced substantial savings. Besides smart thermostats, fan controls are the only other measure present in sufficient numbers in the multifamily measure mix and there is limited evidence that in combination these two measures produce substantial savings in multifamily homes. In addition, the smart-thermostat-only savings shape in Figure 6-16 above is roughly 50% non-multifamily household there is limited evidence of smart thermostat savings in single family and mobile home houses without fan control.

6.5.3 DEER peak period hourly load and savings shapes

We used TMY (CZ2020) data to determine the peak period based on the new 2020 DEER definition and examined hourly load and savings shapes during that period.[58] Figure 6-21 summarizes the hourly load shapes for participants with direct install HVAC measures and comparison households during the defined peak period.[59] It indicates hourly load that is well matched between the two groups, on the left panel, and a reduction in energy use among participants in the post period, on the right panel. While this reduction is small, the estimated savings provided by dwelling type in the table below summarizes the magnitudes of the savings.

Figure 6-21. DEER peak days average hourly electric load shapes for direct install, PY2020

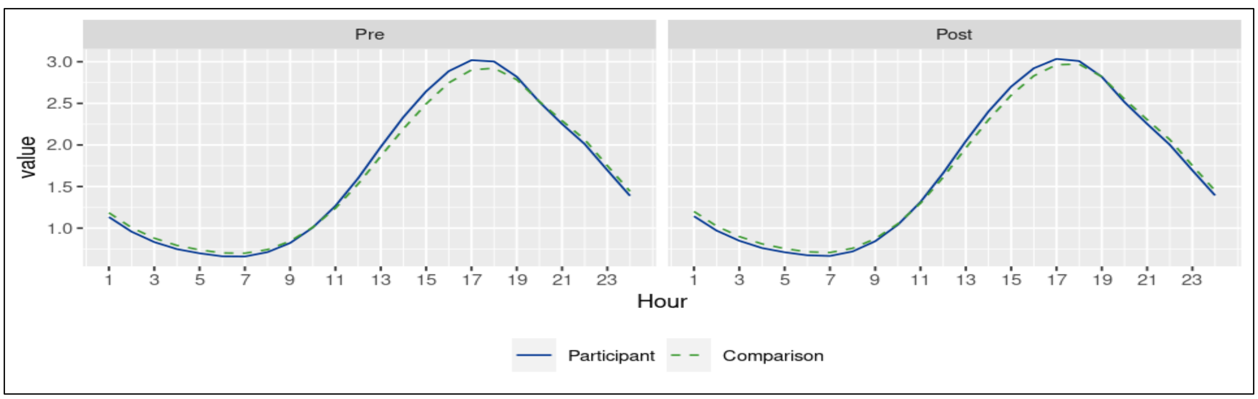


Table 6-6 provides a summary of average hourly load and load reduction (in kW and percent terms) during the DEER peak period that covers the hours of 4 p.m. to 9 p.m. The table provides whole-home load and savings for participants across all homes and by dwelling type. Baseline use is lowest among multifamily homes as is their estimated load reduction. Average

[58] California's Database for Energy Efficient Resources (DEER) defines peak period demand as one that occurs during a heat wave period. It defines a heat wave as 3 consecutive non-holiday weekdays between June 1 and September 30 with the hottest temperatures within the 9-hour window of 4 p.m. to 9 p.m., the new DEER defined window that went into effect in program year 2020 and tracks the actual system peak demand period more closely. This definition considers average temperature, average afternoon temperature (12 p.m.–6 p.m.), and maximum temperature over the course of 3-day heatwave candidates. It requires that the heat wave definition be based on TMY data.

[59] The heat wave periods are mid-August and mid-June for different PG&E and SCE cohorts, and early August and early July for different SDG&E cohorts.

hourly load reduction is highest (almost 2%) for mobile homes in line with the highest kWh reduction estimated for these participants. Average hourly peak reduction across all homes is 0.03 kW, which is about 1% of peak load.

Table 6-6. DEER peak period average hourly baseline and load reductions for direct install, PY2020

Participant Segment	4 p.m. - 9 p.m.			
	household counts	Savings (kW)	Baseline (kW)	Percent savings
All homes	19,474	0.03	2.7	1.2%
Single family	12,001	0.04	3.1	1.3%
Multifamily	3,666	0.01	2.0	0.3%
Mobile home	3,807	0.04	2.4	1.8%

6.6 COVID-19 impacts on energy consumption

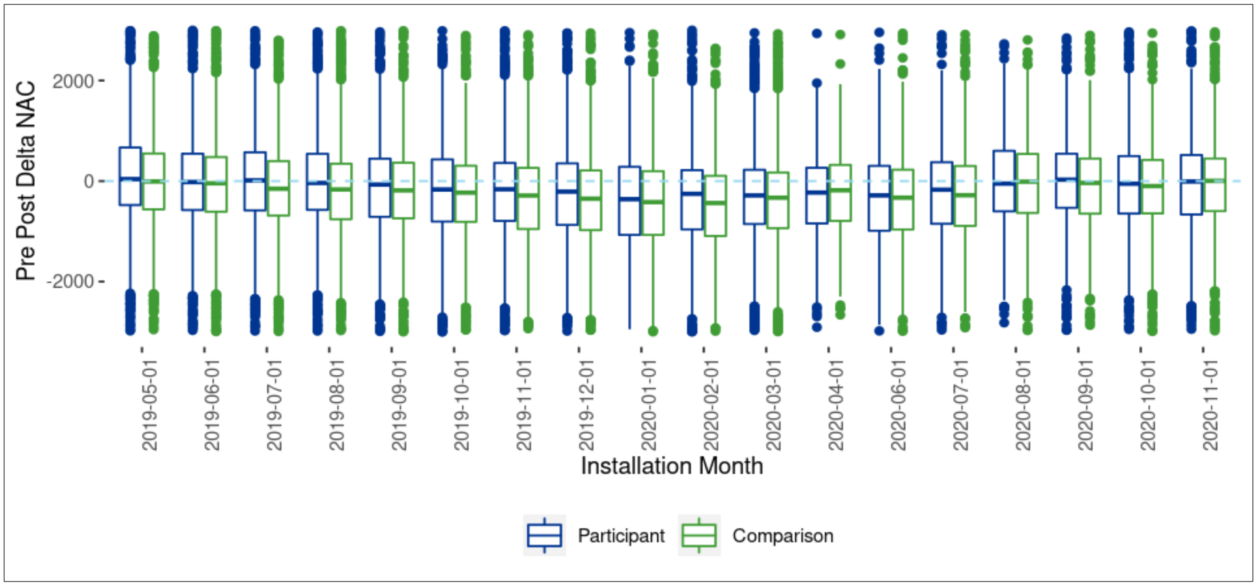
Beginning in March 2020, most residential customers had to spend the bulk of their time, including their working hours, at home following stay-at-home orders in response to the COVID-19 pandemic. With most residential customers working from and spending disproportionate parts of their days at home, energy use levels and patterns were likely different from the pre-COVID-19 era. While the pandemic has upended many aspects of life, it is changes in energy consumption precipitated by this disruption that have likely affected energy efficiency efforts.

One way that DNV examined the extent of these changes was by tracing the pattern of pre-post NAC changes for different participant cohorts and their matched comparison homes.[60] The current evaluation uses data from participants that installed program measures from May 2019 to December 2020. All cohorts have pre- and post-period consumption that are affected by COVID-19 to differing degree. For instance, two months of the first cohort's and three months of the second cohort's post periods fall after the onset of COVID-19. Each subsequent cohort has increasing amounts of its post-period falling during months affected by COVID-19. Starting with May 2020 participants, increasing portions of pre-period consumption were also affected by COVID-19.

To fully trace the trend in energy consumption due to COVID-19, we plotted pre-post differences of weather normalized annual consumption (delta NAC) of different cohorts. Figure 6-22 provides a box plot of electric delta NAC values for participants and matched comparison homes by installation month. Positive values that fall above the blue dotted line indicate decreases in post-period consumption while negative values that fall below the blue dotted line indicate increases in post-period consumption. While there is substantial variation in delta NAC, the bulk of the deltas for each cohort that are within the inter-quartile range become increasingly negative for cohorts from May 2019 onward. In particular, if we fit a curve through the median values of the box plots, it will be possible to see the increasing energy consumption after the onset of the COVID-19 stay-at-home order. As cohorts towards the end of the participation window have more of their pre-period during post-COVID-19, the COVID-19 related increasing trend in consumption becomes attenuated.

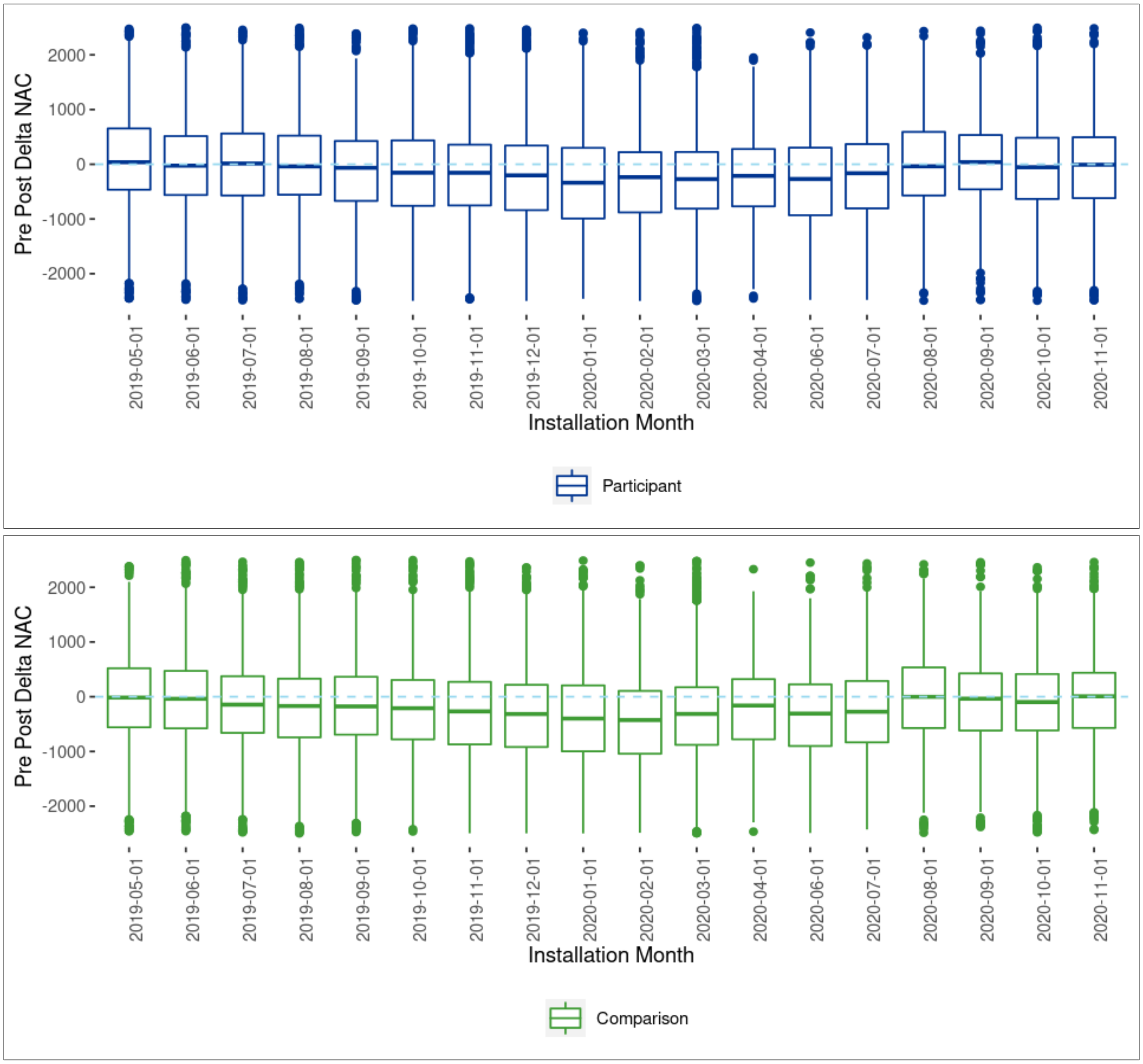
[60]Participants are assigned to a cohort based on their installation month.

Figure 6-22. Pre-post-difference in electric (kWh) NAC for direct install participants and non-participants



It is interesting to note that the use of a comparison group is important to guard against the effects of increasing consumption trends precipitated by such an unusual form of exogenous shock. The comparison group exhibits the same increasing consumption trend and helps mitigate against the effect of this shock on the measurement of the effect of energy efficiency intervention. Figure 6-23 provides the same box plots for participant and non-participant households to make the noted trend more apparent. It also makes it apparent the pre-post difference in NAC is less negative (or more positive) for participants compared to matched non-participants reflecting the energy efficiency gains from program installations.

Figure 6-23. Pre-post-difference in electric (kWh) NAC of direct install participants and matched non-participants



7 CONCLUSIONS AND RECOMMENDATIONS

The findings from this evaluation and resulting recommendations and implications are summarized below.

Table 7-1: Key findings and Recommendations

 Key findings	 Recommendations & Implications
1. Realization rates for rebated smart thermostats improved in PY2020 because ex-ante savings have been reduced based on prior evaluation results. Direct install smart thermostats, fan motor replacements, and fan motor controls continue to have low gross realization rates. Duct testing and sealing continue to have high realization rates.	Continue to adjust ex-ante savings for other measures similarly, particularly for those with fairly stable savings patterns from past evaluations.
2. Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the end use consumption and deliver savings consistently across all seasons.	PAs should continue to include these measures in the residential HVAC program portfolio.
3. While the PY2019 evaluation found no gas savings for smart thermostats delivered through direct install programs, the PY2020 evaluation identified gas savings for this measure that are 40% of claimed savings.	Since these results paint a mixed picture, DNV recommends additional study to examine the consistency and stability of the gas savings potential for smart thermostats.
4. Over half of those not currently enrolled in a DR program expressed some level of interest in participating in a DR program.	PAs should include information on the benefits of DR program participation for customers that receive free or subsidized smart thermostats through EE programs and implement an option to enroll willing customers at the point of installation.
5. For direct install programs, relatively high program attribution and higher burden from COVID-19 suggested by survey results indicate that these programs are reaching the right population segments.	Maintain targeting and outreach to these customers.

 Key findings	 Recommendations & Implications
6. For direct install programs, survey data collection was hampered by lack of reliable information regarding parties responsible for decision-making and lack of contact information for end users for direct install programs.	Prescribe program tracking data requirements that include capturing these specifics.
7. We lack visibility into the electricity consumption of a large number of gas customers for whom electric savings were claimed by SCG. Hence these households are unable to inform the electric savings estimates. This has contributed to poorly determined electric smart thermostat savings for direct install multifamily installations.	Facilitate cross PA identification of customer account IDs for program participants residing in territories served by different electric and gas PAs.

8 APPENDICES

8.1 Appendix A: Gross and net lifecycle savings

Gross and net lifecycle savings are in the attached pdf.

8.2 Appendix B: Per unit (quantity) gross and net energy savings

Per unit (quantity) gross and net energy savings are in the attached pdf.

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 Residential HVAC measures - Program Year 2020	Peter Franzese

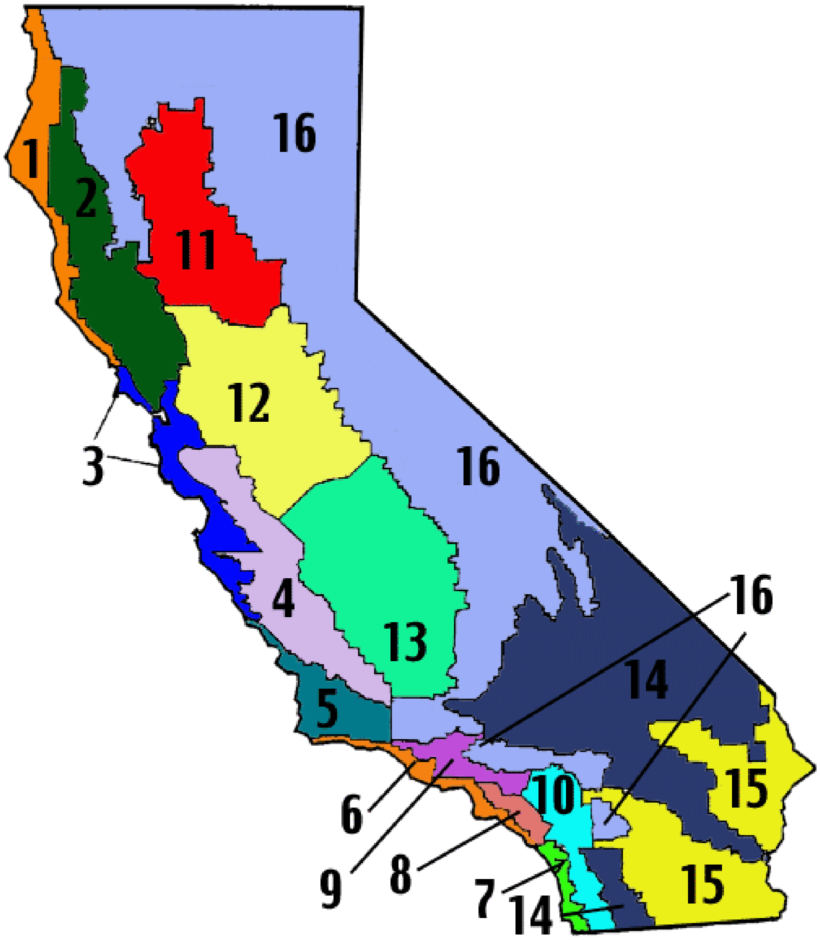
Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
1	Multiple programs delivering HVAC measures	Realization rates for rebated smart thermostats improved in PY2020 because ex-ante savings have been reduced based on prior evaluation results. Direct install smart thermostats, fan motor replacements, and fan motor controls continue to have low gross realization rates. Duct testing and sealing continue to have high realization rates.	Section 6.3	Continue to adjust ex-ante savings for other measures similarly, particularly for those with fairly stable savings patterns from past evaluations.	CPUC, All PAs	Statewide workpaper
2	Multiple programs delivering HVAC measures	Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the end use consumption and deliver savings consistently across all seasons.	Section 6.5	PAs should continue to include these measures in the residential HVAC program portfolio.	CPUC, All PAs	Statewide workpaper
3	Multiple programs delivering smart thermostats	While the PY2019 evaluation found no gas savings for smart thermostats delivered through direct install programs, the PY2020 evaluation identified gas savings for this measure that are 40% of claimed savings.	Section 6.3	Since these results paint a mixed picture, DNV recommends additional study to examine the consistency and stability of the gas savings potential for smart thermostats.	CPUC, All PAs	Statewide workpaper
4	Multiple programs delivering HVAC measures	Over half of those not currently enrolled in a DR program expressed some level of interest in participating in a DR program.	Section 5.2	PAs should include information on the benefits of DR program participation for customers that receive free or subsidized smart thermostats through EE programs and implement an option to enroll willing customers at the point of installation.	CPUC, 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
5	Multiple programs delivering HVAC measures	For direct install programs, relatively high program attribution and higher burden from COVID-19 suggested by survey results indicate that these programs are reaching the right population segments.	Section 5.2	Maintain targeting and outreach to these customers.	All PAs	N/A (Program design consideration)
6	Multiple programs delivering HVAC measures	For direct install programs, survey data collection was hampered by lack of reliable information regarding parties responsible for decision-making and lack of contact information for end users for direct install programs.	Program tracking and Customer Information System (CIS) data	Prescribe program tracking data requirements that include capturing these specifics.	CPUC, All PAs	N/A (Program implementation improvement)
7	Multiple programs delivering HVAC measures	We lack visibility into the electricity consumption of a large number of gas customers for whom electric savings were claimed by SCG. Hence these households are unable to inform the electric savings estimates. This has contributed to poorly determined electric smart thermostat savings for direct install multifamily installations.	CIS data	Facilitate cross PA identification of customer account IDs for program participants residing in territories served by different electric and gas PAs.	CPUC, SCE and SCG	N/A (Program implementation improvement)

8.4 Appendix D: Climate zones

The California Energy Commission has established 16 climate zones (Title 24 climate zone or CEC CZs) that reflect the diversity of climates in the state (Figure). Efficiency standards developed and adopted for various building and measure conditions reflect the varying effect of the CEC CZs.

Figure 8-1. California CEC climate zones



For the purpose of developing survey weightings, we have grouped the 16 CEC CZs into four climate regions: coastal, inland, desert, and mountain. Table 8-1 provides these groupings along with the percent of participants by climate region.

Table 8-1. Climate zone groupings and percent claims by climate region, PY2020

Climate region	CEC climate zone	Percent program participant					
		MCE	PG&E	SCE	SCG	SDG&E	TCR
Coastal/Mild	1,2,3,4,5,6,7	19%	24%	0%	7%	39%	100%
Inland	8,9,10,11,12,13	81%	76%	79%	86%	60%	0%
Desert	14,15	0%	0%	20%	6%	0%	0%
Mountain	16	0%	0%	1%	1%	0%	0%

8.5 Appendix E: Two-stage modeling framework

The consumption data analysis that is the basis of measure savings estimates DNV used, involved a two-stage modeling that combined variable degree-day PRISM-inspired,[61] site-level models with a matched comparison group to estimate program level estimates 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 an 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.[62] The modeling approach is also closely related to all other forms of program analysis that use energy consumption data including time-series, cross-section approaches. Finally, it is also consistent with CalTRACK's recent effort to develop agreed-upon steps for the site-level modeling portion of the analysis.[63]

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.

The two-stage approach relies on the comparison group to control for non-program, exogenous change. It 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.

In the sections that follow, we present the construction of matched comparison groups, and site level and DID modeling approaches used to estimate whole-home savings followed by the approach we used to decompose these savings to measure savings.

[61] Princeton Scorekeeping Method or PRISM is a software tool for estimating energy savings from billing data.

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

[63] CalTRACK specifies a set of empirically tested methods to standardize the way normalized meter-based changes in energy consumption are measured and reported. http://www.caltrack.org/

8.5.1 Site-level modeling

DNV 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 or reference temperature, τ_h.

$C_{im}(\tau_c)$ - Cooling degree-days (CDD) at the cooling base or reference 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.

DNV estimated site-level models using daily energy use data and observed weather data from the NOAA. Consumption was estimated over a range of reference temperatures (64°F to 80°F for cooling and 50°F to 70°F for heating) to identify the optimal temperature base points for each site (household. The site-level models produced 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). First-stage models were screened to remove estimates that had implausible (negative) cooling and heating coefficients.

Model parameter estimates for each site allow the prediction of site-level consumption under any weather condition. For evaluation purposes, all consumption was put on a typical weather basis, using CZ2018 TMY values, and produced an estimate referred to as normalized annual consumption (NAC). NAC for the pre- and post-installation periods were 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:

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

For each home in the analysis, NAC values were determined separately for the pre- and post-installation years and were the basis of the pre-post difference ΔNAC_i (delta NAC). Delta NAC values were in turn the basis of second-stage DID models.

8.5.2 Matched comparison group construction

DNV based its quasi-experimental design on energy consumption data from participants and matched comparison non-participants. Matching underpins the construction of matched comparison groups used in this strategy. It involves the identification of non-participant households that are similar to participants in relevant observable characteristics and whose energy use data can be used to form the baseline against which changes in energy consumption due to program intervention can be evaluated. This approach is commonly used when randomized control trial (RCT) is not feasible to estimate the effect of an intervention.

We constructed matched comparison groups from general population customers for the two-stage consumption data analysis. This effort involved two phases. The first phase identified 10 households for every participant with similar energy use levels (based on monthly billing data) and trends (proxied by tenure[64]) within strata defined by dwelling type and geography. In the second phase, 1-to-1 matches were based on interval consumptions data to choose the optimal household from the initial 10 matches.

In all cases, matching models included annual energy use, the ratio of summer-to-shoulder and winter-to-shoulder energy use to account for seasonality, tenure to control for trend, and variables to capture peak demand conditions (6 p.m. kWh, for electricity, and daily therm, for gas, for identified 'heat wave' periods). For electricity, 'heat wave' periods were identified for each climate zone as weekdays between June through September where most customers had their maximum 6 p.m. kWh. For gas, such periods were based on weekdays from December to February.

DNV used Mahalanobis distance matching without replacement for all matches used in the analysis. Mahalanobis distance matching is scale-invariant and considers correlations of covariates to generate matches that are well-balanced. Balance is tested using standardized mean differences, the ratio of the variance of participant to matched comparison households, and visual inspection of the distribution of covariates of participants to matched comparison households.

The standardized mean difference used to test the condition of matches 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.[65]

8.5.3 DID modeling

To determine the whole-home energy consumption effects of direct install programs, DNV estimated DID models based on the pre-to-post difference in NAC of participant and the matched comparison households.[66] 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 were based on a definition of a blackout period for each participant. According to CalTRACK, a blackout 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."[67]

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[64] Tenure is the length of time, measured in years, that a customer has resided at a premise. DNV's updated PY2018 smart thermostat evaluation to deal with self-selection indicated that tenure is useful proxy for trend in energy use, although its usefulness in matching is limited. http://www.calmac.org/publications/CPUC_Group_A_SCT_PY_2018_Report_Update_final_toCALMAC.pdf

[65] 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

[66] DID models were first used to determine and exclude outliers based on statistical tests; DID values exceeding pre-defined DFITS or studentized residual limits were considered outliers and excluded from the second stage DID models. No more than 2-4% of observations were excluded based on such tests. In addition, sites and their pairs with normalized annual consumption estimates that are not well-determined (with cooling and/or heating estimates that have R-square values of less than 0.1) are excluded from whole-home and measure-level model estimates.

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

Based on the CalTRACK recommendation and the IOU-provided tracking data, DNV defined a blackout period that reflects installation months reported in the tracking data for all the measures installed by the direct install programs that delivered the measure bundles including smart thermostats. All the sites used in this evaluation indicated no more than two installation months for the mix of measures they delivered. These installation dates were used to define a two-month blackout period.

8.5.4 Rebate program trend adjustment

The approach we used to adjust differences in energy consumption trend between rebate program participants and their matches involved adding the percent baseload change to the percent change in non-baseload, where change in both cases is based on pre – post period consumption. The approach attributes all the increase in baseload consumption to self-selection and assumes that non-baseload consumption experiences the same overall percentage increase that is unrelated to the program. The adjustment is given by:

$$Adjusted\ nonbaseload\ savings\ =\ (\%nonbaseload\ change + \%baseload\ change) * estimated\ nonbaseload\ _{post,c}$$

where $estimated\ nonbaseload\ _{post,c} = post\ period\ nonbaseload\ of\ matched\ comparison\ homes$[68]

Expanding the terms in the above equation provides:

$$Adjusted\ nonbaseload\ savings$$

$$= \left(\left(\frac{\Delta nonbaseload}{estimated\ nonbaseload_{post,c}}\right) + \left(\frac{\Delta baseload}{estimated\ baseload_{post,c}}\right)\right) *\ estimated\ nonbaseload_{post,c}$$

$$= \Delta nonbaseload + \left(\frac{\Delta baseload}{estimated\ baseload_{post,c}}\right) *\ estimated\ nonbaseload_{post,c}$$

$$= (\Delta \mathrm{NAC} - \Delta \mathrm{baseload}) + \left(\frac{estimated\ nonbaseload_{post,c}}{estimated\ baseload_{post,c}}\right) * \Delta baseload$$

$$= (\Delta \mathrm{NAC} - \Delta \mathrm{baseload}) + \left(\frac{(NAC - baseload)_{post,c}}{estimated\ baseload_{post,c}}\right) * \Delta baseload$$

$$= (\Delta \mathrm{NAC} - \Delta \mathrm{baseload}) + A * \Delta baseload$$

Thus, while the basic model uses delta NAC as a function of a treatment indicator to estimate rebate program savings, DNV’s adjusted model uses delta non-baseload corrected for apparent trend for the same purpose. The regression model for the adjusted non-baseload is specified by:

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

where:

$$\Delta adjNonbaseload_i =\ \Delta NAC_i - \Delta Baseload_i - A * \Delta Baseload_i$$

$$\Delta NAC_i = NAC_{pre,i} -\ NAC_{post,i}$$

$$\Delta Baseload_i = Baseload_{pre,i} -\ Baseload_{post,i}$$

$$A = (NAC_{post,c} - Baseload_{post,c})/Baseload_{post,c}$$

[68] This post period energy consumption of non-participants proxies what the consumption of participants would have been had they not participated in the program and serves as baseline consumption.

In these models, i subscripts a household (treatment or comparison), T is a treatment indicator that is 1 for households with rebated smart thermostats and 0 for matched comparison homes, and ε is an error term. The effect of the rebate programs is captured by the coefficient estimate, $\hat{\beta}$.

8.6 Appendix F: Matching Results

The quasi-experimental design that DNV used in this study involved the identification of comparison group customers that served as matches for residential HVAC participants. This section provides results from the two-phase matching that DNV 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.

8.6.1 First-phase matching results

Table 8-2 provides values of the metrics used to test balance. These metrics are computed based on annual consumption of participants and selected candidate matches after matching. In general, standardized mean differences and the ratios of variance of annual consumption for the matched groups show that the selected 15:1 matches are relatively well balanced. The standardized differences for the matched groups are all well below 0.2 (are no higher than 0.003) and the ratio of variances are close to 1 and generally indicate the variance of annual usage of the matched groups is similar.

Table 8-2. First-phase matching test of balance

PA	Fuel	Standardized Mean Difference	Variance Ratio
PGE&E	electric	0.002	1.0
	gas	0.000	1.0
SCE	electric	0.003	1.0
SCG	gas	0.000	1.0
SDG&E	electric	0.001	1.0
	gas	0.002	1.0

8.6.2 Second-phase matching results

The quasi-experimental design we use to model whole-home, and ultimately, residential HVAC measures savings are based on 1:1 matches of participants and general population non-participants with similar pre-period energy use patterns. We present the state of balance for the second and final stage of matches conducted for this purpose.

Interval data from the 15:1 participant to non-participant matches based on monthly billing data were the basis of the second phase 1:1 matches. These matches led to the selection of non-participant households that were best matches for the participants. These matches provide the conditions for a robust analysis of the effect of residential HVAC measures on energy consumption changes since they control for non-program related changes effectively.

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 8-3). As in the first-phase matching, total consumption of the matched groups was used to compute the test of balance metrics. The standardized mean differences are near zero, with 95% confidence bounds that in absolute value are no higher than 0.06. Tests of balance on all other matching variables including tenure indicated that the two groups used in the analysis had data that were well balanced.

Table 8-3. Second-phase matching test of balance

PA	Fuel	Standardized Mean Difference	Lower	Upper
PGE&E	electric	0.00	-0.02	0.02
	gas	0.00	-0.02	0.02
SCE	electric	0.00	-0.02	0.03
SCG	gas	0.00	-0.01	0.02
SDG&E	electric	0.01	-0.05	0.06
	gas	0.00	-0.04	0.05

Figure 8-2 through Figure 8-7 illustrate the quality of matches for the selected matched samples graphically. Each panel provides the distribution of variables for participant and matched non-participant homes. Each indicates that these distributions are very similar and that the data that are well balanced.

Figure 8-2. Distribution of PG&E matched electric data

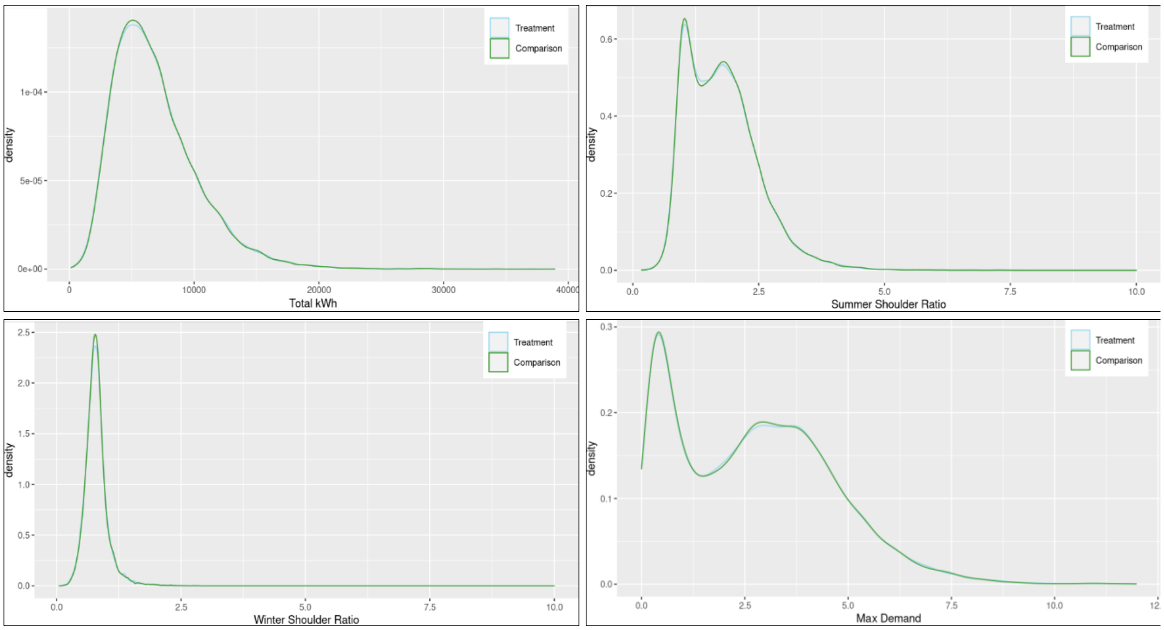


Figure 8-3. Distribution of PG&E matched gas data

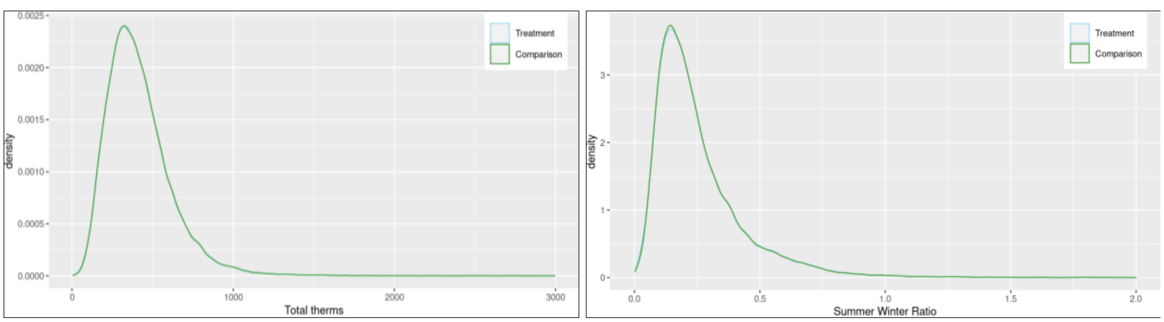


Figure 8-4. Distribution of SCE matched electric data

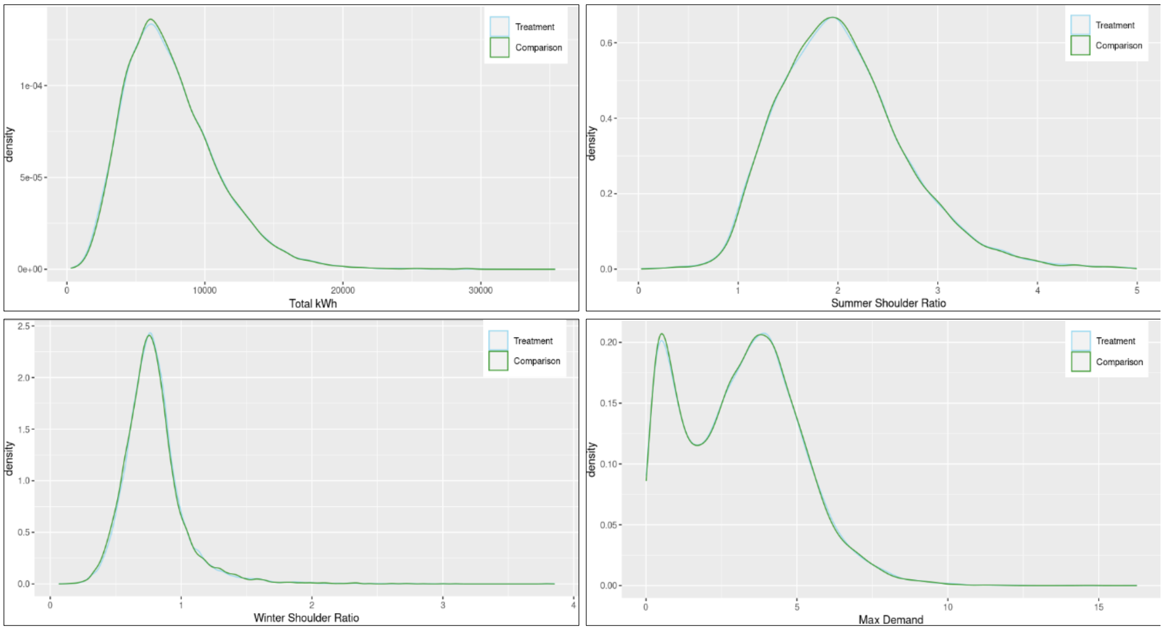


Figure 8-5. Distribution of SCG matched gas data

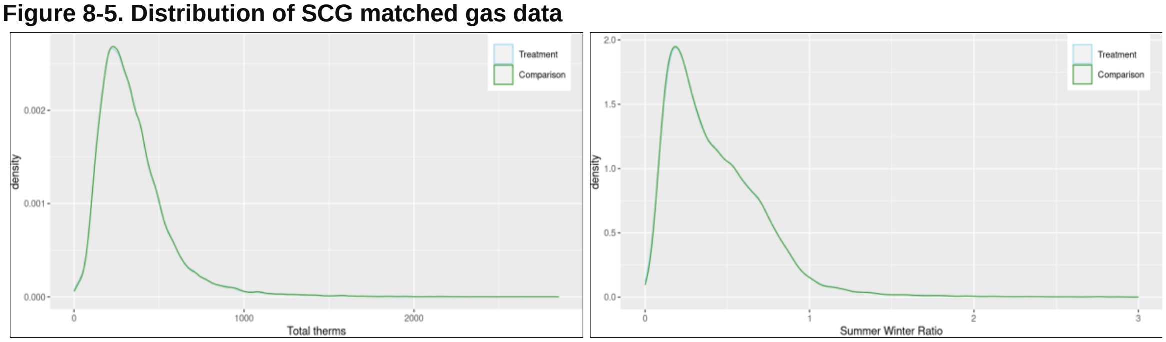


Figure 8-6. Distribution of SDG&E matched electric data

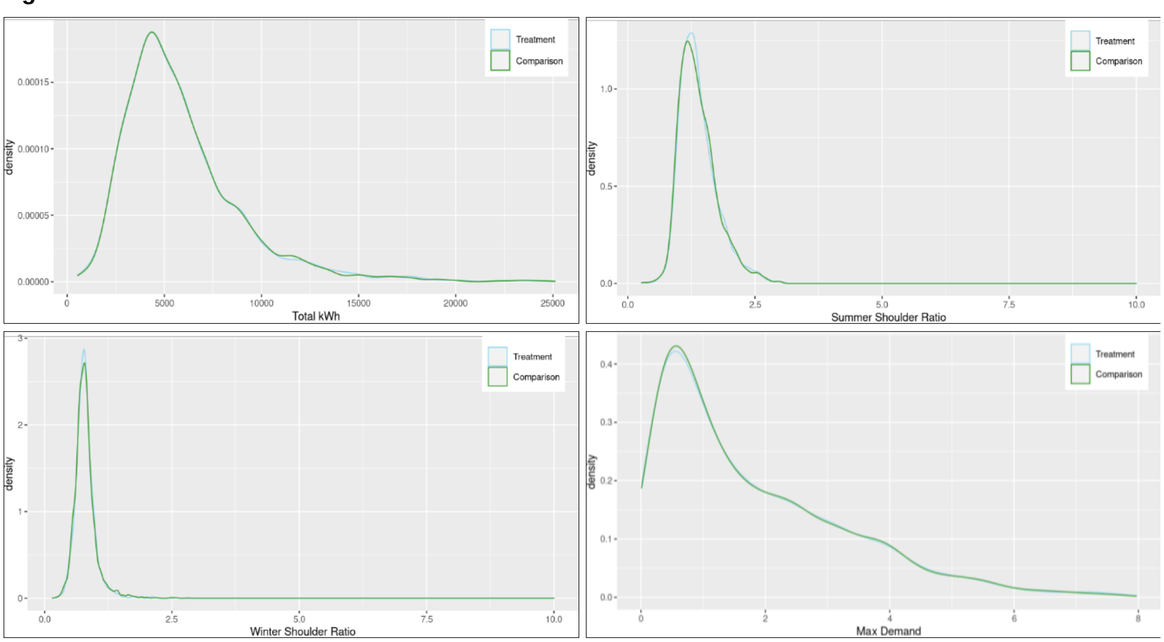
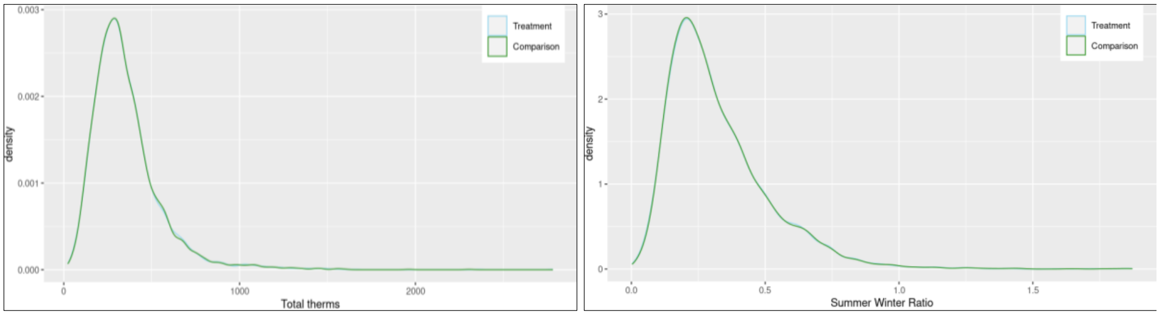


Figure 8-7. Distribution of SDG&E matched gas data



8.6.3 Quality of matches from additional variables

In addition to testing balance on consumption and tenure data used for the matching, DNV tested the condition of balance based on additional household characteristics data that the IOUs provided. The figures below show the distributions of these characteristics for participants and their matched comparison groups, respectively, where the matches were based on consumption and tenure only. The figures show good correspondence between the participants and matched comparison groups on these additional dimensions.

Figure 8-8. Comparison group assessment by homeownership

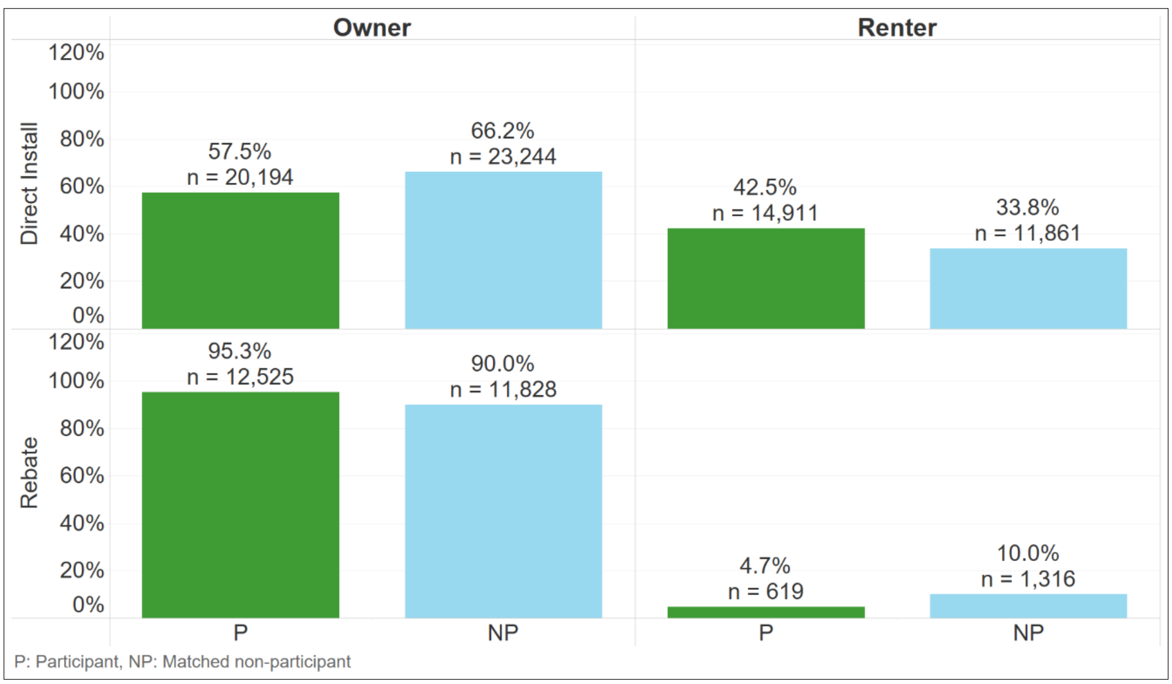
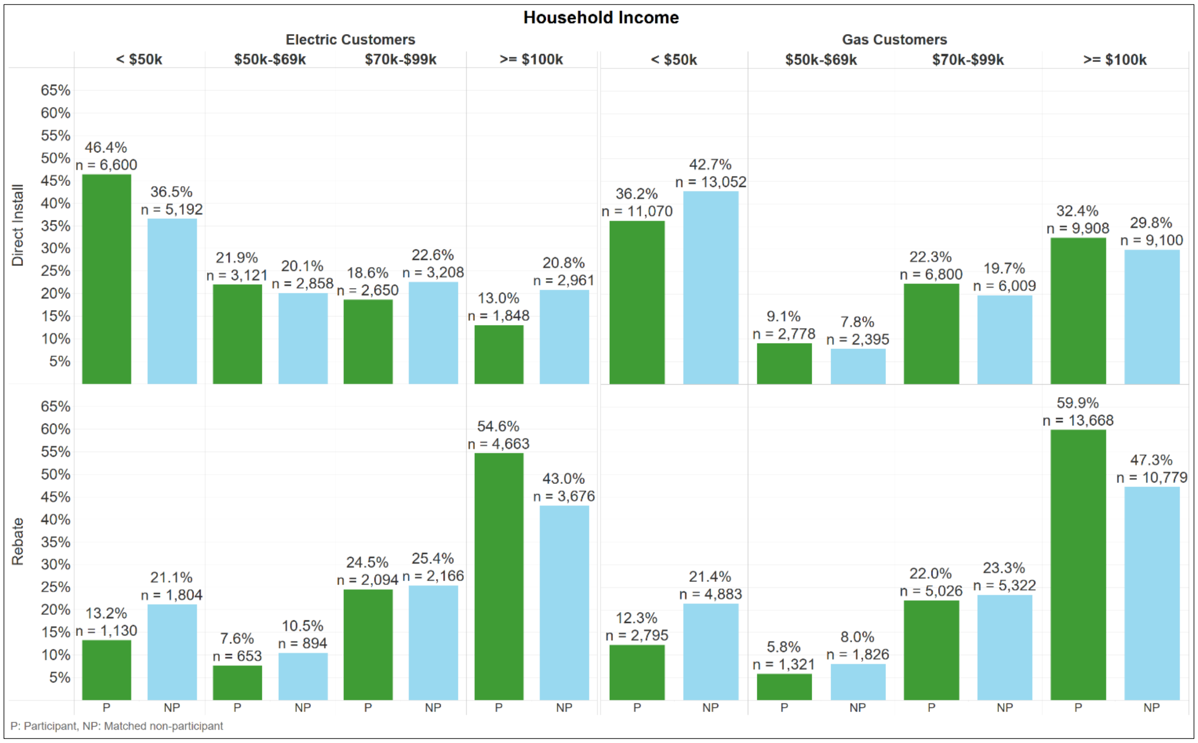


Figure 8-9. Comparison group assessment by household income



8.7 Appendix G: Second-stage DID model results

This section presents all second-stage DID model results starting with models used to evaluate rebate installations and then models used to evaluate direct install measures.

8.7.1 Rebate installation models

As indicated in 3.2.1.1, DNV estimated whole-home savings for participants with rebated smart thermostats based on a model that adjusts for the energy consumption trend differential between participants and non-participants. This trend differential is measured by the increase in baseload for participants compared to non-participants post-installation. While the two groups are well-matched before the installation of the rebated measure, there are factors that lead participants to increase their energy consumption at a higher rate than the non-participants they are matched.

Table 8-4 provides estimates from NAC models that indicate the increase in overall energy use by participants due to the trend differential, which is captured by the estimated baseload increase also provided in the table. The table provides the estimated whole-home electric and gas savings based on the model that adjusts for the trend differential. These estimates indicate an electric savings of 81 kWh or 1% of total electric load and 2.3 therms or half a percent total gas load.

Table 8-4. Rebate electric and gas whole-home savings models, PY2020

Model type	intercept	DID estimate	DID standard error	DID p value	savings (%)
Electric (kWh)					
NAC	-274.7	-103.7	17.91	0.00	-1%
Baseload	-209.0	-140.1	16.02	0.00	-3%
Adjusted non-baseload	1.4	81.4	14.47	0.00	1%
Gas (therms)					
NAC	5.1	-2.5	0.99	0.01	-1%

Baseload	-4.4	-2.1	0.61	0.00	-1%
Adjusted non-baseload	15.4	2.3	1.28	0.08	0.5%

The second-stage DID models used to measure the percent electric and gas baseload increases for customers that participated in rebate programs and presented in Section 6.1 are provided in Table 8-5. The table provides estimates by dwelling type. Because the percent of mobile home participants is very low, we used the model based on all participants to proxy the increase in mobile home baseload increases.

Table 8-5. Rebate electric and gas baseload savings models by dwelling type, PY2020

Fuel	Model type	Variable	Dwelling type	N	Estimate	standard error	p-value
Electric	Baseline baseload	Intercept	Mobile home	7,595	5,536	30.6	0.0
			Multifamily	289	4,075	102.1	0.0
			Single family	7,292	5,596	31.4	0.0
		treat	Mobile home	7,595	191	43.2	0.0
			Multifamily	289	195	144.4	0.2
			Single family	7292	190	44.3	0.0
	DID	Intercept	Mobile home	7,595	-208	10.7	0.0
			Multifamily	289	-144	45.9	0.0
			Single family	7292	-211	11.0	0.0
		treat	Mobile home	7,595	-135	15.1	0.0
			Multifamily	289	-210	64.9	0.0
			Single family	7,292	-131	15.6	0.0
Gas	Baseline baseload	Intercept	Mobile home	25,456	197.8	0.7	0.0
			Multifamily	518	166	4.3	0.0
			Single family	24,902	198	0.7	0.0
		treat	Mobile home	25,456	4.5	1.0	0.0
			Multifamily	518	7.6	6.0	0.2
			Single family	24902	4.6	1.0	0.0
	DID	Intercept	Mobile home	25,456	-3.9	0.4	0.0
			Multifamily	518	-4.6	2.5	0.1
			Single family	24,902	-3.9	0.4	0.0
		treat	Mobile home	25,456	-3.2	0.5	0.0
			Multifamily	518	-4.4	3.5	0.2
			Single family	24,902	-3.2	0.6	0.0

Table 8-6 provides DID model results that are the basis of the percent electric and gas baseload changes for customers that participated in direct install programs. These models indicate no evidence of an increasing energy consumption trend for these participants.

Table 8-6. Direct install electric and gas baseload savings models by dwelling type, PY2020

Fuel	Model type	Variable	Dwelling type	N	Estimate	standard error	p-value
Electric	Baseline baseload	Intercept	Mobile home	3,425	4,125	31.37	0.00
			Multifamily	3,394	3,362	26.73	0.00
			Single family	11,191	5,529	23.08	0.00
		treat	Mobile home	3,425	-172	44.37	0.00
			Multifamily	3,394	10	37.80	0.79
			Single family	11,191	-16	32.64	0.63
	DID	Intercept	Mobile home	3,425	-98	12.05	0.00
			Multifamily	3,394	-132	11.63	0.00
			Single family	11,191	-205	9.05	0.00
		treat	Mobile home	3,425	67	17.04	0.00
			Multifamily	3,394	-30	16.45	0.07
			Single family	11,191	34	12.80	0.01
Gas	Baseline baseload	Intercept	Mobile home	2,710	163	1.73	0.00
			Multifamily	10,447	182	0.80	0.00
			Single family	10,448	205	1.16	0.00
		treat	Mobile home	2,710	-5.9	2.45	0.02

			Multifamily	10,447	0.5	1.13	0.63
			Single family	10,448	0.8	1.65	0.63
	DID	Intercept	Mobile home	2,710	0.2	0.88	0.84
			Multifamily	10,447	-1.2	0.50	0.02
			Single family	10,448	-3.9	0.52	0.00
		treat	Mobile home	2,710	2.9	1.25	0.02
			Multifamily	10,447	-0.4	0.71	0.57
			Single family	10,448	2.3	0.74	0.00

8.7.2 Direct install models

The simplest second stage DID dummy model estimates average consumption change for participants while controlling for comparison group trends. A better-informed model would include simulated savings as an independent variable to allow for variation in simulated measure bundle savings across participants. In this case, the regression determines the mix of the constant dummy and variable measure bundle savings effects that best reflects the variation in the dependent variable.

A further step recognizes that savings, particularly HVAC savings, are likely to vary as a function of the size of a home. To increase model flexibility that addresses this, both sides of the regression are divided by consumption to put variables on a percentage basis. The pre-post consumption dependent variable is divided by pre-period consumption while the bundle of engineering simulation value on the right side is divided by simulation model baseline consumption. Again, the regression determines the mix of the constant dummy and percent simulated measure bundle savings effects that best reflects the empirical data entering the model in the dependent variable. Details of this model are provided in Section 3.2.2.

Table 8-7 provides results from the percent change model. The general trend estimates (B_t) indicate a decline in energy use if positive and an increase if positive. The adjustment factors (B_adj) reflect what fraction of expected savings of the installed measures were realized by the mix of measures installed by the direct install programs.

Table 8-7. Direct install electric and gas models of percent change in annual whole-home consumption, PY2020

Dwelling type	intercept	P value	B_t	P value	B_adj	P value
Electric						
Mobile home	-0.034	0.000	0.009	0.124	0.140	0.000
Multifamily	-0.046	0.000	-0.005	0.361	0.186	0.077
Single family	-0.043	0.000	0.003	0.365	0.124	0.002
Gas						
Mobile home	-0.003	0.377	-0.003	0.650	-0.052	0.507
Multifamily	-0.036	0.000	0.015	0.000	-0.226	0.073
Single family	-0.035	0.000	0.024	0.000	0.094	0.117

Whole-home consumption change estimates from the above model are disaggregated using the proportion of simulated energy savings of installed measures at each site as indicated in Section 3.2.2. Table 8-8 provides estimates of both whole-home and measure level electric savings.

Table 8-8. Direct install electric whole-home and measure-level savings models by dwelling type, PY2020

Model type	Dwelling Type	Model estimates		
		savings (kWh)	standard error	p value
Whole-home	Mobile home	170	25	0.0
	Multifamily	9	24	0.7
	Single family	88	18	0.0
Smart thermostats	Mobile home	37	9	0.0
	Multifamily	-6	17	0.7
	Single family	16	6	0.0
Fan motor replacement	Mobile home	132	17	0.0
	Multifamily	48	31	0.1

	Single family	72	13	0.0
Fan motor controls	Mobile home	69	10	0.0
	Multifamily	17	17	0.3
	Single family	38	8	0.0
Duct testing and sealing	Mobile home	136	17	0.0
	Multifamily			
	Single family	91	16	0.0

Table 8-9 provides estimates of whole-home and measure level gas savings for direct install programs.

Table 8-9. Direct install gas whole-home and measure-level savings models by dwelling type, PY2020

Model type	Dwelling Type	Model estimates		
		savings (kWh)	standard error	p value
Whole-home	Mobile home	-2.7	2.0	0.2
	Multifamily	3.4	0.9	0.0
	Single family	12.5	1.3	0.0
Smart thermostats	Mobile home	-1.0	1.4	0.5
	Multifamily	3.1	0.8	0.0
	Single family	8.7	1.1	0.0
Duct testing and sealing	Mobile home	-3.1	2.2	0.2
	Multifamily			
	Single family	11.3	1.9	0.0

As a check on the disaggregated savings, we also estimated savings for measures that are installed alone. Smart thermostats were the only measure installed alone in sufficient numbers for use in models. Table 8-10 provides estimates of electric savings from smart thermostats installed alone through direct install programs.

Table 8-10. Direct install electric savings models for smart thermostat-only installation by dwelling type, PY2020

Model type	Dwelling Type	N	Model estimates		
			savings (kWh)	standard error	p value
Whole-home	Mobile home	434	34	71	0.6
	Multifamily	1,692	-28	36	0.4
	Single family	1,250	8	55	0.9

Table 8-11 estimates of electric savings from smart thermostats installed alone through direct install programs. Results from both the electric and gas savings from these models are presented in Section 6.

Table 8-11. Direct install gas savings models for smart thermostat-only installation by dwelling type, PY2020

Model type	Dwelling Type	N	Model estimates		
			savings (therms)	standard error	p value
Whole-home	Mobile home	850	-6.2	3.6	0.1
	Multifamily	11,329	0.6	1.0	0.5
	Single family	7,839	14.9	1.7	0.0

8.7.3 Savings adjustment for comparison group smart thermostat installations

Smart thermostat savings estimates for direct install participants were adjusted upward to account for the prevalence of smart thermostats among the comparison group. Results from surveys of direct install comparison group households revealed that 9% to 13% installed smart thermostats in 2020. These are periods during which participants installed smart thermostats and the effect of smart thermostats on energy consumption are measured for this group. If comparison group smart thermostat installations are assumed to have the same savings effect in the matched comparison households as program thermostats, then their presence will have the effect of diminishing the magnitude of participant savings estimates coming directly from the model coefficients.

Table 8-12 provides the installation rates of smart thermostats among the comparison group and the multiplicative adjustment factors used to account for these rates by dwelling type. For example, a prevalence of 12.8% smart thermostats among comparison group households requires that savings estimates be divided by (1-0.128 = 0.872) or multiplied by its reciprocal (1.15). This is a modest upward adjustment that assumes that all comparison group installations perfectly correlate with the timing of program participant installations.

Table 8-12. Adjustment factors for the presence of smart thermostats among the comparison groups by dwelling type, PY2020

Dwelling Type	PY2020 Installations	Effect on Estimated Savings
Mobile home	9.1%	1.10
Multifamily	12.0%	1.14
Single family	12.8%	1.15

8.7.4 Electric and gas measure and whole-home savings estimates by dwelling type and climate zone

Table 8-13 provides measure and whole-home electric (kWh) savings by dwelling type and climate zone.

Table 8-13. Measure and whole-home electric (kWh) savings by dwelling type and climate zone, PY2020

Dwelling type	Climate zone	Duct testing and sealing	Fan motor controls	Fan motor replacement	Smart thermostat	Whole-home
DMO	2	216	54	132	25	214
	3	60	44	131	29	169
	4	96	48	102	29	147
	6	86	26		28	118
	8	104	46	37	34	104
	9	123	52	109	41	125
	10	139	61	123	34	159
	11		68	115	23	159
	12	129	61	127	29	163
	13	141	79	143	37	192
	14	130	74	134	44	107
	15	161	102	149	62	217
	16	130	63	112	27	166
MFM	2		45	98	17	160
	6				-13	-13
	8				-11	-11
	9				-10	-10
	10				-12	-13
	11		14	51	3	24
	12		43	85	10	30
	13		17	48	-5	10
	14				-16	-16
SFM	2					36
	3		14	40	4	37
	4					12
	6			54	18	31
	8		30	40	23	36
	9	105	32	49	27	65
	10	86	30	67	17	85
	11		29	65	25	41
	12	103	29	63	15	59
	13	108	40	74	14	94
	14	103	34	72	19	77
	15	155	63	117	27	132
	16	42	9	50	10	54

Table 8-14 provides measure and whole-home gas (therm) savings by dwelling type and climate zone.

Table 8-14. Measure and whole-home gas (therm) savings by dwelling type and climate zone, PY2020

Dwelling type	Climate zone	Duct testing and sealing	Smart thermostat	Whole-home
DMO	2	-6		-6
	3	-3	-2	-2
	4	-4	-2	-3
	6	-2	-1	-2
	8	-3	-1	-3
	9	-3	-1	-3
	10	-3	-1	-3
	11		-2	-2
	12	-4	-1	-3
	13	-3	-1	-3
	14	-5	-1	-4
	15	-2	-1	-2
	16	-7	-1	-5
MFM	2		10	10
	6		4	4
	8		3	3
	9		3	3
	10		3	3
	11		4	4
	12		6	6
	13		4	4
SFM	2			16
	3		9	11
	4		14	14
	5		4	13
	6	8	11	12
	8		7	10
	9	11	11	11
	10	11	4	12
	11		10	13
	12	14	11	12
	13	14	9	11
	14	18	6	16
	15	5	3	8
	16	17	10	11

8.8 Appendix H: Electric and gas load by dwelling type and climate zone

Table 8-15 provides estimates of average electric baseload, cooling, and heating load across all direct install participants by dwelling type and climate zone. It also includes NAC, which is the sum of the three components, along with the count of households (N) with data in each dwelling type and climate zone.

Table 8-15. Direct install electric load components by dwelling type and climate zone, PY2020

Dwelling type	climate zone	N	baseload	cooling load	heating load	NAC
DMO	2	2	7,159	449	876	8,484
	3	12	4,839	906	243	5,988
	4	68	4,100	415	367	4,882
	6	29	4,660	474	239	5,373
	8	157	3,474	1,188	139	4,800
	9	124	3,779	1,592	202	5,572

	10	1147	3,947	1,868	221	6,037
	11	86	4,159	1,504	387	6,050
	12	609	4,211	1,743	475	6,428
	13	1020	4,009	2,701	280	6,989
	14	151	3,952	1,670	313	5,935
	15	289	3,961	3,713	154	7,828
	16	4	3,573	1,518	504	5,595
MFM	2	1	11,601	838	670	13,109
	3	1	1,690	235	0	1,925
	6	23	3,212	785	76	4,073
	8	64	2,676	793	95	3,564
	9	39	3,234	578	222	4,033
	10	142	2,672	1,296	88	4,057
	11	105	2,163	1,832	97	4,092
	12	13	4,359	1,613	813	6,785
	13	3129	3,345	2,263	119	5,727
	14	18	3,403	844	606	4,853
SFM	2	6	7,515	1,300	563	9,378
	3	5	4,936	418	503	5,858
	4	1	2,903	302	0	3,206
	6	4	5,556	141	272	5,969
	8	46	6,118	1,303	146	7,567
	9	39	6,350	1,872	263	8,485
	10	3236	5,456	2,288	236	7,980
	11	250	5,914	2,282	445	8,641
	12	939	5,703	1,847	489	8,039
	13	5389	5,390	3,124	342	8,856
	14	1324	5,475	2,135	361	7,971
	15	390	5,405	4,977	142	10,524
	16	115	4,553	2,294	334	7,180

Table 8-16 provides estimates of average gas baseload and heating load across all direct install participants by dwelling type and climate zone. It also includes NAC, which is the sum of the two components, along with the count of households (N) with data in each dwelling type and climate zone.

Table 8-16. Direct install gas load components by dwelling type and climate zone, PY2020

Dwelling type	climate zone	N	baseload	heating load	NAC
DMO	2	2	225	476	702
	3	15	180	208	388
	4	50	325	161	486
	6	19	181	152	333
	8	62	205	151	356
	9	161	192	160	353
	10	1,151	161	203	364
	11	7	118	303	421
	12	523	143	254	398
	13	449	171	202	374
	14	26	205	251	456
	15	401	142	129	271
	16	7	197	431	629
MFM	6	1,170	207	95	302
	8	6,040	174	62	236
	9	4,753	214	70	284
	10	781	174	62	236

	11	138	180	137	317
	12	4	167	287	454
	13	2,550	157	116	274
SFM	2	1	404	192	596
	3	3	227	201	428
	4	2	189	392	580
	5	27	276	174	450
	6	191	283	215	498
	8	233	204	184	388
	9	5,386	231	229	459
	10	2,425	218	196	414
	11	7	220	272	492
	12	645	182	277	459
	13	1,769	199	220	419
	14	130	221	305	525
	15	338	199	102	302
	16	255	211	229	440

Table 8-17 provides estimates of average electric baseload, cooling and heating load, and NAC across all rebate program participants by climate zone. Since almost all participants are single family residents, no breakdown by dwelling type is provided. It also includes the count of households (N) with data in each climate zone.

Table 8-17. Rebate electric load components by climate zone

climate zone	N	baseload	cooling load	heating load	NAC
1	2	12,329	0	915	13,244
2	209	5,669	731	456	6,856
3	825	4,797	265	626	5,688
4	1,214	5,221	574	454	6,249
5	33	5,026	248	507	5,781
6	266	5,756	671	354	6,780
7	707	4,608	875	232	5,715
8	516	5,167	1,154	219	6,540
9	431	5,669	1,493	284	7,446
10	914	5,299	1,593	211	7,104
11	332	6,245	2,132	375	8,753
12	1,357	5,831	1,671	366	7,868
13	679	5,948	3,096	271	9,315
14	71	5,650	2,248	334	8,233
15	33	5,123	3,687	343	9,152
16	30	5,470	1,318	695	7,482

Table 8-18 provides estimates of average gas baseload, heating load, and NAC across all rebate program participants by climate zone. It also includes the count of households (N) with data in climate zone.

Table 8-18. Rebate gas load components by climate zone

climate zone	N	baseload	heating load	NAC
1	36	260	448	708
2	504	194	328	521
3	2,133	216	320	536

4	2,024	192	330	522
5	128	213	220	433
6	932	212	218	429
7	1,393	180	188	367
8	1,521	192	196	388
9	3,007	207	237	443
10	2,418	186	205	390
11	753	187	313	500
12	2,937	181	301	482
13	948	178	271	448
14	214	194	320	514
15	175	155	140	295
16	104	200	354	554

8.9 Appendix I: NTGR survey scoring

For the residential HVAC impact evaluation, DNV used NTGR scoring methods similar to those used for other residential measures. DNV's standard NTGR approach assesses three dimensions of free-ridership: timing, quantity, and efficiency. The program induces savings if it accelerates the timing of an efficient measure installation, if it increases the number installed, or if it raises the efficiency level of what was installed.

The timing dimension is relevant for all measures. Quantity and efficiency are relevant for some measures and not for others. For example, for duct sealing, it is almost always the case that the entire duct system is treated at once, so quantity would always be 1. Similarly, the ducts are either sealed or not, so there is not a variable level of efficiency like there would be for a furnace. The following measures and dimensions are covered in the PY2020 evaluation:

- **Smart thermostats (timing, efficiency, quantity for multifamily) -** For smart thermostats, the survey determined "efficiency" in terms of the type of thermostat that would otherwise have been installed but rated these at only 2 levels—smart (efficient) or not. Single-family program participants could only receive a single smart thermostat, so that the quantity dimension is not applicable. However, survey respondents who are multifamily property managers[69] 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 multifamily survey respondents.
- **Fan motor replacement (timing, efficiency)** – In situ fan motors could be repaired or replaced with a standard rather than a brushless motor.
- **Fan motor controls (timing, quantity for multifamily)** – DNV assumed a single fan motor per household. As a controller, it is either installed or not – there are not varying levels of efficiency for controllers. Survey respondents who are multifamily property managers could be responsible for multiple homes and could have decided to install the in more or fewer units. Thus, the quantity dimension is applicable to multifamily survey respondents.
- **Duct sealing (timing, quantity for multifamily)** – as noted above, duct sealing happens for the entire home and there are not variable levels of sealing completed. Survey respondents who are multifamily property

[69] 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.

managers could be responsible for multiple homes and could have decided to install the in more or fewer units. Thus, the quantity dimension is applicable to multifamily survey respondents.

The NTGR survey scoring elements are summarized below in Table 8-19.

Table 8-19. Free-ridership elements by survey respondent type, PY2020

Survey Respondents	Free-ridership Dimension	Question Wording	Answer	Free-Ridership Score
Participants (occupants)	Timing – (FR_t)	Without [PA]'s program offering when would you have completed the project?	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
Property managers	Timing – (FR_t)	If the program didn't offer smart thermostats in 2020, when would you have purchased and installed them…? Without the program, when would you have taken on this DUCT SEAL project…? Without the program offering the installation on {DATE}, when do you think you would have had the indoor FAN MOTOR CONTROLLER installed? Without the program, when do you think you would have had the FAN MOTOR installed?	At the same time or sooner	1
			1 to 48 months later	48 - # of months)/48
			More than 48 months	0
			Never	0
			Don't know	Average of non-Don't know answers

<table>
<tr><th>Survey Respondents</th><th>Free-ridership Dimension</th><th>Question Wording</th><th>Answer</th><th>Free-Ridership Score</th></tr>
<tr><td rowspan="4">Participants (occupants)

Property managers</td><td rowspan="4">Thermostat “Efficiency” (FR_e)</td><td rowspan="4">Smart thermostats come in a variety of models. There are BASIC models that cost about $150-$200 (e.g., Nest E and Ecobee 3 lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest Learning 3rd Gen and Ecobee 4).


If the program didn’t offer a smart thermostat in 2020, which model would you have likely purchased?</td><td>Would have purchased the BASIC model smart thermostat(s)</td><td>1</td></tr>
<tr><td>Would have purchased the UPGRADED model smart thermostat(s)</td><td>1</td></tr>
<tr><td>Would have purchased standard programmable thermostat(s); (e.g., without smart capabilities)</td><td>0</td></tr>
<tr><td>Would NOT have purchased any thermostat(s)</td><td>0</td></tr>
<tr><td rowspan="5">Participants (occupants)

Property managers</td><td rowspan="5">Fan motor Efficiency (FR_e)</td><td rowspan="5">For the next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician install a new high efficiency indoor Fan Motor on the furnace (heating) unit.

Without the program, which of the following would you have done?</td><td>Replace with a high efficiency motor (i.e. brushless)</td><td>1</td></tr>
<tr><td>Replace with a standard motor</td><td>0</td></tr>
<tr><td>Repair the existing equipment</td><td>0</td></tr>
<tr><td>Nothing, no replacement or repair</td><td>0</td></tr>
<tr><td>Don't know</td><td>Average of non-Don't know responses</td></tr>
<tr><td rowspan="3">Property Managers</td><td rowspan="3">Quantity FR_q</td><td>Without {PA}’s program how many smart thermostats would your company had installed at their expense? As a reminder, {PA} records show {number} were installed. Using the scale below, please specify the percentage you would have installed without the program.</td><td rowspan="3">0%, 100%, 1% to 100% in 10% increments</td><td rowspan="3">0%, 100%, or mid-point of increment</td></tr>
<tr><td>Without {PA}'s program how many units provided with this/these duct test service(s) would you have completed without the program? Please specify the percentage you would have completed:</td></tr>
<tr><td>Without {PA}'s program how many units provided with fan motor controllers would you have completed without the program? Please specify the percentage you would have completed:</td></tr>
</table>

Using these metrics in combination allowed DNV to fully assess the amount of savings that could be attributed to measures that participants would have installed absent program support. DNV 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 single-family participants

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

Equation 2: Free-ridership Scoring Algorithm for multifamily participants

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

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) or property manager surveys are summarized in Section 5.2.1. 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.

8.10 Appendix J: NTGR survey results

Participant and property manager survey based free-ridership estimates are weighted by electric PA gross savings claims to arrive at final electric program attribution estimates. Responses reveal a general pattern of lower levels of free-ridership and higher program attribution of kWh savings for direct install programs relative to rebate programs at 74% to 90% versus 43% to 75%. Program attribution scores for electric savings for residential HVAC measures (NTGRs) by program, delivery mechanism, and PA are summarized in Table 8-20.

Table 8-20. Residential HVAC electric program attribution (NTGR) by PA program, delivery mechanism, and survey

<table>
<tr><th rowspan="2">Delivery Mechanism</th><th rowspan="2">Program ID</th><th rowspan="2">Program Name</th><th rowspan="2">PA Gross Savings Claims (kWh)</th><th rowspan="2">% Savings</th><th rowspan="2">Survey</th><th colspan="3">NTGR</th><th rowspan="2">PA Relative Precision[70] +/-</th></tr>
<tr><th>Program</th><th>Type</th><th>PA</th></tr>
<tr><td>Rebate</td><td>PGE21002</td><td>Residential Energy Efficiency</td><td>920,910</td><td>26%</td><td>Participant</td><td>45%</td><td>45%</td><td rowspan="4">78%</td><td rowspan="4">6%</td></tr>
<tr><td rowspan="3">Direct Install</td><td>PGE210011</td><td>Residential Energy Fitness program</td><td>15,027</td><td>0%</td><td>Participant</td><td>71%</td><td rowspan="3">90%</td></tr>
<tr><td>PGE21008</td><td>Enhance Time Delay Relay</td><td>1,311,538</td><td>37%</td><td>Property Manager</td><td>86%</td></tr>
<tr><td>PGE21009</td><td>Direct Install for Manufactured and Mobile Homes</td><td>1,274,455</td><td>36%</td><td>Participant</td><td>94%</td></tr>
<tr><td>Rebate</td><td>SCE-13-SW-001B</td><td>Plug Load and Appliances Program</td><td>2,598</td><td>0%</td><td>Participant</td><td>75%</td><td>75%</td><td rowspan="3">84%</td><td rowspan="3">2%</td></tr>
<tr><td rowspan="2">Direct Install</td><td>SCE-13-SW-001G</td><td>Residential Direct Install Program</td><td>6,949,556</td><td>85%</td><td>Participant</td><td>84%</td><td rowspan="2">84%</td></tr>
<tr><td>SCE-13-TP-001</td><td>Comprehensive Manufactured Homes</td><td>1,234,883</td><td>15%</td><td>Participant</td><td>82%</td></tr>
<tr><td>Rebate</td><td>SCG3702</td><td>RES-Residential Energy Efficiency Program</td><td>1,296,015</td><td>58%</td><td>Participant</td><td>43%</td><td>43%</td><td rowspan="5">56%</td><td rowspan="5">7%</td></tr>
<tr><td rowspan="4">Direct Install</td><td>SCG3762</td><td>RES-CLEO</td><td>15,639</td><td>1%</td><td>Participant</td><td>79%</td><td rowspan="4">74%</td></tr>
<tr><td>SCG3820</td><td>RES-Direct Install Program</td><td>48,422</td><td>2%</td><td>Participant</td><td>70%</td></tr>
<tr><td>SCG3763</td><td>RES-MF Direct Therm Savings</td><td>349,059</td><td>16%</td><td>Participant</td><td>67%</td></tr>
<tr><td>SCG3765</td><td>RES-Manufactured Mobile Home</td><td>514,907</td><td>23%</td><td>Participant</td><td>80%</td></tr>
<tr><td>Rebate</td><td>SDGE3204</td><td>SW-CALS-Plug Load and Appliances-POS Rebates</td><td>638,495</td><td>54%</td><td>Property Manager</td><td>50%</td><td>50%</td><td rowspan="2">67%</td><td rowspan="2">5%</td></tr>
<tr><td>Direct Install</td><td>SDGE3279</td><td>3P-Res-Comprehensive Manufactured-Mobile Home</td><td>549,840</td><td>46%</td><td>Property Manager</td><td>86%</td><td>86%</td></tr>
</table>

Participant and property manager survey-based free-ridership estimates were also weighted by gas PA gross savings claims to arrive at final gas program attribution estimates. As expected, the survey reveals a similar pattern of lower levels of free-ridership and higher program attribution of therms savings for direct install programs relative to rebate programs at 72% to 84% versus 45% to 66%, respectively. Program attribution scores for gas savings for residential HVAC measures (NTGRs) by program, delivery mechanism, and PA are summarized in Table 8-21.

[70] Precision is reported at 90% confidence level.

Table 8-21. Residential HVAC gas program attribution (NTGR) by PA program, delivery mechanism, and survey

Delivery Mechanism	Program ID	Program Name	PA Gross Savings Claims (therms)	% Savings	Survey	NTGR			PA Relative Precision[71] +/-
						Program	Type	PA	
Rebate	PGE21002	Residential Energy Efficiency	228,257	85%	Participant	47%	47%	50%	5%
Direct Install	PGE210011	Residential Energy Fitness program	486	0%	Participant	71%	72%		
	PGE21008	Enhance Time Delay Relay	24,028	9%	Property Manager	60%			
	PGE21009	Direct Install for Manufactured and Mobile Homes	14,315	5%	Participant	93%			
Rebate	SCE-13-SW-001B	Plug Load and Appliances Program	276	0%	Participant	66%	66%	84%	2%
Direct Install	SCE-13-SW-001G	Residential Direct Install Program	91,766	91%	Participant	84%	84%		
	SCE-13-TP-001	Comprehensive Manufactured Homes	9,271	9%	Participant	83%			
Rebate	SCG3702	RES-Residential Energy Efficiency Program	100,781	51%	Participant	45%	45%	58%	8%
Direct Install	SCG3762	RES-CLEO	1,070	1%	Participant	77%	73%		
	SCG3820	RES-Direct Install Program	26,087	13%	Participant	77%			
	SCG3763	RES-MF Direct Therm Savings	60,711	31%	Participant	69%			
	SCG3765	RES-Manufactured Mobile Home	9,630	5%	Participant	84%			
Rebate	SDGE3204	SW-CALS-Plug Load and Appliances-POS Rebates	44,014	93%	Property Manager	52%	52%	54%	6%
Direct Install	SDGE3279	3P-Res-Comprehensive Manufactured-Mobile Home	3,086	7%	Property Manager	81%	81%		

Table 8-22 summarizes NTGRs for electric savings by measure, program type, and dwelling type. It indicates higher attribution for the measures delivered by direct install programs versus those delivered by rebate programs.

Table 8-22. NTGRs for electric savings for residential HVAC measures by measure, program type, and dwelling type

Measure - Program Type	Dwelling Type	Gross Savings Claims (kWh)	% Savings	NTGR		Relative Precision
				Dwelling	Delivery	
Smart thermostat - Rebate	Single Family	2,833,359	18.7%	46%	46%	28.9%
	Multi Family	20,426	0.1%	40%		
	Mobile Home	10,283	0.1%	56%		
Smart thermostat – Direct Install	Single Family	2,131,355	14.1%	83%	80%	8.6%

[71] Precision is reported at 90% confidence level.

Measure - Program Type	Dwelling Type	Gross Savings Claims (kWh)	% Savings	NTGR		Relative Precision
				Dwelling	Delivery	
	Multi Family	981,264	6.5%	67%		
	Mobile Home	1,282,879	8.5%	87%		
Motor Replacements – Direct Install	Single Family	3,361,226	22.2%	85%	89%	2.8%
	Multi Family	496,013	3.3%	100%		
	Mobile Home	825,007	5.5%	93%		
Fan controls – Direct Install	Single Family	1,469,015	9.7%	83%	86%	2.9%
	Multi Family	371,648	2.5%	100%		
	Mobile Home	1,014,392	6.7%	85%		
Duct Sealing – Direct Install	Single Family	70,010	0.5%	78%	79%	4.5%
	Multi Family	85,359	0.6%	100%		
	Mobile Home	175,157	1.2%	75%		

Table 8-23 provides NTG for gas savings by measure group, program type, and dwelling type. It also indicates higher attribution for measures delivered by direct install programs versus rebate programs.

Table 8-23. NTGRs for gas savings for residential HVAC measures by measure, program type, and dwelling type

Measure – Program type	Dwelling Type	Gross Savings Claims (Therms)	% Savings	NTGR		Relative Precision
				Dwelling	Delivery	
Smart thermostat - Rebate	Single Family	367,066	57.8%	47%	47%	22.4%
	Multi Family	5,759	0.9%	46%		
	Mobile Home	776	0.1%	58%		
Smart thermostat - Direct install	Single Family	174,769	27.5%	81%	78%	6.6%
	Multi Family	88,786	14.0%	68%		
	Mobile Home	40,239	6.3%	90%		
Duct Sealing – Direct Install	Single Family	7,172	1.1%	78%	80%	4.3%
	Multi Family	1,252	0.2%	100%		
	Mobile Home	2,402	0.4%	79%		

8.11 Appendix K: Sample weights

DNV presents summaries of the sample weights developed for the participant net to gross ratio in this section. The approach used to compute and assess weights is summarized below.

- Survey samples were post-stratified by delivery mechanism, building type, measure group, and first year kWh savings.
- For each cell, DNV calculated the proportion of the population and the proportion of the sample in each cell.
- The proportional sample weight is calculated as the ratio of the population proportion to the sample proportion.
- DNV screened these weights for extremely low or high values.
- Any cells where there were few (n< 3) to no sample points, strata were collapsed

With this approach, the results for each cell determined from the sample are weighted by the proportion of participants in the full program population from that cell to calculate a weighted average.

Participant survey for Net to Gross - sample weights. Participant surveys were post-stratified by delivery mechanism (direct install/rebate), building type (Single Family, Multi-Family, Mobile Home), measure group (Control Fans, Smart Thermostats, and Duct Sealing), and savings (first year gross kWh) magnitude. For each cell, the weight was calculated as the ratio of participants in the program population to the number of participants in the responding sample for that cell. Participants can be either individual customers or property managers. With this approach, the responses for a cell are weighted by the total number of participants in the program with similar savings contributions. For example, a property manager responsible for many smart thermostat measures would represent a larger gross savings than an individual participant that installed a single measure. The table presents the final post stratification results including the population and sample counts, strata cut points, total first year savings, and weight for each cell. The table indicates a balanced survey sample with the differential weights providing minor corrections for over and under representation (Table 8-24). The rebate delivery single-family motor replacement measure group had no sample but had only one claim in the population.

Table 8-24. Program participant sample weights

Delivery Mechanism	Building Type	Measure Group	Stratum	Maximum	Accounts	First Year Gross Savings (kWh)	Sample	Weight
Direct Install	Single Family	CONTROLS FAN	1	901	1,284	333,812	52	24.7
Direct Install	Single Family	CONTROLS FAN	2	1,041	2,280	695,032	43	53.0
Direct Install	Single Family	CONTROLS FAN	3	1,888	573	313,619	28	20.5
Direct Install	Single Family	CONTROLS FAN	4	5,828	138	126,552	7	19.7
Direct Install	Single Family	CONTROLS SMART THERMOSTAT	5	1,486	7,706	808,230	333	23.1
Direct Install	Single Family	CONTROLS SMART THERMOSTAT	6	2,536	3,181	619,553	85	37.4
Direct Install	Single Family	CONTROLS SMART THERMOSTAT	7	3,793	1,706	693,269	79	21.6
Direct Install	Single Family	CONTROLS SMART THERMOSTAT	8	26,359	145	10,303	10	14.5
Direct Install	Single Family	DUCT SEALING	9	284	827	11,886	27	30.6
Direct Install	Single Family	DUCT SEALING	10	475	698	21,448	36	19.4
Direct Install	Single Family	DUCT SEALING	11	563	197	7,724	11	17.9

Delivery Mechanism	Building Type	Measure Group	Stratum	Maximum	Accounts	First Year Gross Savings (kWh)	Sample	Weight
Direct Install	Single Family	DUCT SEALING	12	751	316	15,665	11	28.7
Direct Install	Single Family	DUCT SEALING	13	6,757	165	13,286	7	23.6
Direct Install	Single Family	MOTOR REPLACEMENT	14	757	2,758	891,258	98	28.1
Direct Install	Single Family	MOTOR REPLACEMENT	15	865	1,774	716,306	48	37.0
Direct Install	Single Family	MOTOR REPLACEMENT	16	1,081	800	422,313	33	24.2
Direct Install	Single Family	MOTOR REPLACEMENT	17	1,577	1,105	665,368	52	21.3
Direct Install	Single Family	MOTOR REPLACEMENT	18	5,180	766	665,980	42	18.2
Direct Install	Multi Family	CONTROLS FAN	19	67,767	229	371,648	16	14.3
Direct Install	Multi Family	CONTROLS SMART THERMOSTAT	20	975	4,297	152,337	95	45.2
Direct Install	Multi Family	CONTROLS SMART THERMOSTAT	21	1,901	3,088	215,226	41	75.3
Direct Install	Multi Family	CONTROLS SMART THERMOSTAT	22	14,052	125	86,012	7	17.9
Direct Install	Multi Family	CONTROLS SMART THERMOSTAT	23	173,477	91	527,689	16	5.7
Direct Install	Multi Family	DUCT SEALING	24	25,074	172	85,359	1	172.0
Direct Install	Multi Family	MOTOR REPLACEMENT	25	10,312	179	196,443	25	7.2
Direct Install	Multi Family	MOTOR REPLACEMENT	26	61,816	30	299,570	2	15.0
Direct Install	Mobile Home	CONTROLS FAN	27	1,400	1,247	452,015	85	14.7
Direct Install	Mobile Home	CONTROLS FAN	28	73,165	635	562,377	22	28.9
Direct Install	Mobile Home	CONTROLS SMART THERMOSTAT	29	2,215	1,826	460,992	117	15.6
Direct Install	Mobile Home	CONTROLS SMART THERMOSTAT	30	2,701	1,057	505,295	61	17.3
Direct Install	Mobile Home	CONTROLS SMART THERMOSTAT	31	133,284	188	316,592	8	23.5
Direct Install	Mobile Home	DUCT SEALING	32	396	801	40,661	32	25.0
Direct Install	Mobile Home	DUCT SEALING	33	489	395	35,966	18	21.9
Direct Install	Mobile Home	DUCT SEALING	34	570	379	44,797	20	19.0
Direct Install	Mobile Home	DUCT SEALING	35	18,582	195	53,733	10	19.5
Direct Install	Mobile Home	MOTOR REPLACEMENT	36	746	674	175,472	39	17.3
Direct Install	Mobile Home	MOTOR REPLACEMENT	37	924	310	108,036	13	23.9
Direct Install	Mobile Home	MOTOR REPLACEMENT	38	1,232	390	166,016	20	19.5
Direct Install	Mobile Home	MOTOR REPLACEMENT	39	2,578	170	106,018	14	12.1
Direct Install	Mobile Home	MOTOR REPLACEMENT	40	46,880	50	269,465	1	50.0
Rebate	Single Family	CONTROLS SMART THERMOSTAT	41	1,486	14,542	1,145,934	927	15.7
Rebate	Single Family	CONTROLS SMART THERMOSTAT	42	1,586	3,984	566,478	431	9.2
Rebate	Single Family	CONTROLS SMART THERMOSTAT	43	2,476	5,580	618,431	782	7.1

Delivery Mechanism	Building Type	Measure Group	Stratum	Maximum	Accounts	First Year Gross Savings (kWh)	Sample	Weight
Rebate	Single Family	CONTROLS SMART THERMOSTAT	44	2,850	4,123	397,659	543	7.6
Rebate	Single Family	CONTROLS SMART THERMOSTAT	45	5,699	1,005	104,857	136	7.4
Rebate	Single Family	MOTOR REPLACEMENT	46	808	1	379	-	
Rebate	Multi Family	CONTROLS SMART THERMOSTAT	47	887	649	8,247	88	7.0
Rebate	Multi Family	CONTROLS SMART THERMOSTAT	48	1,901	162	12,179	14	12.0
Rebate	Mobile Home	CONTROLS SMART THERMOSTAT	49	2,215	28	4,254	3	9.0
Rebate	Mobile Home	CONTROLS SMART THERMOSTAT	50	4,106	22	6,029	5	4.0

DNV presents summaries of the sample weights developed for the participant and non-participant surveys in this section. The approach used to compute and assess weights is summarized below.

- Survey samples were post-stratified by PA, CZ group, and annual consumption (kBtu) level.
- For each cell, DNV calculated the proportion of the population and the proportion of the sample in each cell.
- The proportional sample weight is calculated as the ratio of the population proportion to the sample proportion.
- The weight represents the number of customers in the participant population represented by the participant or matched non-participant survey respondent
- Any cells where there were few (n< 3) to no sample points, strata were collapsed

For the demographic analysis for both participants and non-participants, annual consumption (kBtu) was used as the stratification variable to provide a consistent extrapolation variable known for both populations. Tracking savings which was used as the stratification variable for the net to gross analysis is only available for program participants which resulted in the need for distinct post stratification methodologies for the net to gross and demographic analyses.

Participant survey – sample weights. The team applied sample weights, in order to balance the participant survey sample to the population proportions by each PA, climate zone category, and annual consumption (kBtu) level combinations (Table 8-25). The 4 climate zone categories used in the weight develop are outlined in (Table 8-1). This range indicates a balanced survey sample, with the differential weights providing minor corrections for over and under representation.

Table 8-25. Participant survey sample weights

PA	Climate Region	Stratum	Maximum	Accounts	Annual Consumption (kBtu)	Sample	Weight
PG&E	coastal	1	16,768	3,320	28,080,936	513	6.5
PG&E	coastal	2	28,485	1,541	33,374,946	241	6.4
PG&E	coastal	3	4,427,050	841	43,779,317	106	7.9
PG&E	inland	4	22,913	7,535	89,594,646	1,338	5.6
PG&E	inland	5	54,296	3,316	107,411,534	434	7.6
PG&E	inland	6	10,363,253	454	247,343,942	42	10.8
PG&E	mountain	7	96,798	53	1,010,491	7	7.6

PA	Climate Region	Stratum	Maximum	Accounts	Annual Consumption (kBtu)	Sample	Weight
SCE	coastal	8	797,940	10	2,721,766	1	10
SCE	inland	9	39,834	7,879	174,552,746	283	27.8
SCE	inland	10	14,752,163	1,259	406,480,697	30	42
SCE	desert	11	42,304	2,194	50,573,177	115	19.1
SCE	desert	12	8,978,952	283	121,456,928	8	35.4
SCE	mountain	13	4,928,931	64	6,263,706	5	12.8
SDG&E	coastal	14	13,335	2,045	14,204,921	186	11
SDG&E	coastal	15	22,401	954	16,580,036	66	14.5
SDG&E	coastal	16	131,010	592	18,850,900	34	17.4
SDG&E	inland	17	9,982,962	3,146	226,232,801	265	11.9
SDG&E	desert	18	22,466	39	460,390	4	9.8
SDG&E	desert	19	80,326	16	623,729	4	4
SCG	coastal	20	42,199	1,770	38,754,974	116	15.3
SCG	coastal	21	79,599	810	45,506,312	59	13.7
SCG	coastal	22	20,594,408	245	86,092,942	15	16.3
SCG	inland	23	70,499	16,746	485,940,486	897	18.7
SCG	inland	24	37,090,614	1,865	1,219,064,364	93	20.1
SCG	desert	25	16,712,001	1,285	301,232,200	95	13.5
SCG	mountain	26	31,300	1,944	34,249,981	32	60.8
SCG	mountain	27	48,999	993	39,328,660	24	41.4
SCG	mountain	28	6,431,547	618	48,023,052	16	38.6

Non-participant survey - sample weights. The team applied the same sample weighting methodology, in order to balance the non-participant survey sample to the participant survey population proportions by each PA, climate zone category, and annual consumption (kBtu) level combinations (Table 8-26). Optimized strata cut points were developed for the participant population and then these same cut points were applied to the non-participant survey respondents to have a consistent population to weight up to. With the exception of SCG Mountain stratum 26 and PG&E Mountain stratum 7 the non-participant survey provided a balanced survey sample with the differential weights providing minor corrections for over and under representation. All results presented in the report are calculated across the dimensions of the sample design and not at the PA/climate zone/consumption level. Because of this, the overall results will not be skewed by the few customers with large weights (>80) in post stratification methodology.

Table 8-26. Non-participant survey sample weights

PA	Climate Region	Stratum	Maximum	Accounts	Annual Consumpti on (kBtu)	Sample	Weight
PG&E	coastal	1	16,768	3,320	28,080,936	37	89.7
PG&E	coastal	2	28,485	1,541	33,374,946	57	27.0
PG&E	coastal	3	4,427,050	841	43,779,317	524	1.6
PG&E	inland	4	22,913	7,535	89,594,646	133	56.7
PG&E	inland	5	54,296	3,316	107,411,534	493	6.7
PG&E	inland	6	10,363,253	454	247,343,942	551	0.8

PA	Climate Region	Stratum	Maximum	Accounts	Annual Consumption (kBtu)	Sample	Weight
PG&E	mountain	7	96,798	53	1,010,491	1	53.0
SCE	coastal	8	797,940	10	2,721,766	61	0.2
SCE	inland	9	39,834	7,879	174,552,746	1,028	7.7
SCE	inland	10	14,752,163	1,259	406,480,697	119	10.6
SCE	desert	11	42,304	2,194	50,573,177	322	6.8
SCE	desert	12	8,978,952	283	121,456,928	42	6.7
SCE	mountain	13	4,928,931	64	6,263,706	25	2.6
SDG&E	coastal	14	13,335	2,045	14,204,921	78	26.2
SDG&E	coastal	15	22,401	954	16,580,036	131	7.3
SDG&E	coastal	16	999,999	592	18,850,900	1,178	0.5
SDG&E	inland	17	9,982,962	3,146	226,232,801	897	3.5
SDG&E	desert	18	22,466	39	460,390	4	9.8
SDG&E	desert	19	80,326	16	623,729	5	3.2
SCG	coastal	20	42,199	1,770	38,754,974	158	11.2
SCG	coastal	21	79,599	810	45,506,312	67	12.1
SCG	coastal	22	20,594,408	245	86,092,942	7	35.0
SCG	inland	23	70,499	16,746	485,940,486	1,471	11.4
SCG	inland	24	37,090,614	1,865	1,219,064,364	120	15.5
SCG	desert	25	16,712,001	1,285	301,232,200	84	15.3
SCG	mountain	26	31,300	1,944	34,249,981	3	648.0
SCG	mountain	27	48,999	993	39,328,660	11	90.3
SCG	mountain	28	6,431,547	618	48,023,052	14	44.1

8.12 Appendix L: Detailed survey tables

Detailed survey results by program and dwelling type are presented in this section.

8.12.1 COVID-19 impacts

Table 8-27 presents COVID-19 impacts reported by single family, multi-family, and mobile home occupants.

Table 8-27. Detailed results - COVID-19 impact on household, PY2020

Program type	Rebate	Rebate	DI	DI	Rebate	Rebate	DI	DI	DI	DI
Dwelling type	SF	SF	SF	SF	MF	MF	MF	MF	MH	MH
Participation status	NP	P	NP	P	NP	P	NP	P	NP	P
Sample size – n	4,363	2,818	2,650	559	85	102	486	131	267	235
Group notation / COVID-19 impacts	a	b	c	d	e	f	g	h	i	j
Unemployment by one or more household member	20%[b]	19%[d]	19%	28%[c]	27%[f]	15%[h]	22%[h]	43%[g]	11%[j]	16%
Lost wages by one or more household member	24%[b]	24%[d]	24%	32%[c]	33%[f]	23%[h]	25%	40%[g]	16%[j]	23%
Forwent basic necessities to pay energy bill in the last year	18%[b]	16%[d]	22%	33%[c]	18%[f]	11%[h]	24%	49%[g]	27%[j]	32%
Kept home at an unsafe/ unhealthy temperature in the last year	8%[b]	6%[d]	7%	9%[c]	9%[f]	4%[h]	7%	15%[g]	6%[j]	8%
Unable to pay some or full bill in the last year	10%[b]	6%[d]	13%	23%[c]	10%	6%[h]	17%	37%[g]	11%[j]	13%

8.12.2 Changes in home impacting energy use

Table 8-28 presents self-reported changes in the household impacting energy use among participants and non-participants. Results are summarized by program and dwelling type.

Table 8-28. Detailed results - Changes in home impacting energy use, PY2020

Program type	Rebate	Rebate	DI	DI	Rebate	Rebate	DI	DI	DI	DI
Dwelling type	SF	SF	SF	SF	MF	MF	MF	MF	MH	MH
Participation status	NP	P	NP	P	NP	P	NP	P	NP	P
Sample size – n	4,363	2,818	2,650	559	85	102	486	131	267	235
Group notation / COVID-19 impacts	a	b	c	d	e	f	g	h	i	j
Added electric vehicle charging to the home	2%[b]	9%[d]	2%	0%[c]	15%[f]	4%	1%[h]	-1%	0%[j]	0%
Using an additional refrigerator	6%[b]	8%[d]	5%	15%[c]	1%[f]	6%	1%	1%	6%[j]	4%
Household size increased	-1%b[b]	4%[d]	-3%	5%[c]	-9%[f]	3%	-1%[h]	-3%	-3%[j]	-2%
Increased living area/square footage of your home	0%[b]	4%[d]	0%	2%[c]	1%[f]	-1%	-1%[h]	1%	-1%[j]	-3%
Added a pool/pool pump	0%	1%[d]	-1%	1%[c]	8%[f]	0%	-1%[h]	-3%	-1%[j]	-1%
Added a spa	-1%[b]	-1%[d]	-2%	-1%[c]	4%[f]	-1%	0%[h]	-3%	1%[j]	0%
Using more lighting	-3%[b]	5%[d]	-8%	-5%[c]	-11%[f]	23%	-3%[h]	-8%	-6%[j]	-7%
Note: 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.										

8.12.3 Smart thermostat use

Table 8-29 summarizes customers' previous and current thermostat use habits. Results are presented by program and dwelling type.

Table 8-29. Detailed results - Comparison of previous thermostat and current smart thermostat use, PY2020

Program type	Rebate	Rebate	DI	DI	Rebate	Rebate	DI	DI	DI	DI
Dwelling type	SF	SF	SF	SF	MF	MF	MF	MF	MH	MH
Participation status	NP	P	NP	P	NP	P	NP	P	NP	P
Sample size – n	873	2,818	590	507	13	102	77	131	41	183
Group notation / Characteristic	a	b	c	d	e	f	g	h	i	j
Previous Thermostat Habits										
Reduce the temperature when away from home during the day	25%[b]	24%[d]	18%	22%[c]	33%	23%[h]	22%	12%[g]	30%[j]	39%
Thermostat is switched off when away from home during the day	34%[b]	43%[d]	31%	53%[c]	44%[f]	29%[h]	18%	66%[g]	24%[j]	35%
Reduce the temperature when asleep/overnight	41%[b]	42%[d]	34%	38%[c]	34%	34%	35%	33%	45%	48%
Thermostat is switched off when asleep/overnight	18%[b]	22%[d]	15%	26%[c]	31%	17%[h]	7%	36%[g]	13%[j]	26%
Smart Thermostat Habits										
Reduce the temperature when away from home during the day	40%[b]	42%[d]	30%	35%[c]	67%[f]	45%[h]	30%	20%[g]	40%	39%
Thermostat is switched off when away from home during the day	30%[b]	46%	29%	45%[c]	32%	43%[h]	27%	66%[g]	26%[j]	31%
Reduce the temperature when asleep/overnight	54%[b]	64%[d]	47%	49%[c]	87%[f]	60%[h]	52%	42%[g]	67%[j]	53%
Thermostat is switched off when asleep/overnight	15%[b]	18%	10%	18%[c]	0%	18%[h]	8%	31%[g]	6%[j]	22%
Provided some setting preferences and minimal programming of thermostat	20%[b]	17%[d]	21%	18%[c]	24%	19%[h]	17%	16%	14%[j]	24%
Program thermostat settings per schedule and comfort needs	49%[b]	56%[d]	37%	38%[c]	35%[f]	58%[h]	57%	32%[g]	47%[j]	39%
Let the smart thermostat programming/algorithm learn the household's habits and set an automatic schedule	12%[b]	15%[d]	15%	9%[c]	30%	12%[h]	2%	9%[g]	8%	2%

Table 8-30 summarizes smart thermostat use by participants and non-participants who acquired thermostats outside the program. Results are presented by program and dwelling type.

Table 8-30. Detailed results - Smart thermostat non-participant and participant user profile, PY2020

Program type	Rebate	Rebate	DI	DI	Rebate	Rebate	DI	DI	DI	DI
Dwelling type	SF	SF	SF	SF	MF	MF	MF	MF	MH	MH
Participation status	NP	P	NP	P	NP	P	NP	P	NP	P
Sample size – n	873	2,818	590	507	13	102	77	131	41	183
Group notation / Characteristic	a	b	c	d	e	f	g	h	i	j
Smart Thermostat Use										
Very or somewhat satisfied with smart thermostat	71%[b]	69%[d]	70%	59%[c]	82%	74%[h]	62%	53%[g]	66%[j]	53%
Use the mobile app to access smart thermostat	89%[b]	75%[d]	89%	50%[c]	89%[f]	81%[h]	95%	35%[g]	75%[j]	32%
Remotely adjust home temperature using app	74%[b]	67%[d]	70%	44%[c]	87%[f]	71%[h]	75%	32%[g]	57%[j]	27%
Pre-cool or pre-heat home using app	18%[b]	22%[d]	18%	10%[c]	3%[f]	26%[h]	16%	8%[g]	20%[j]	2%
More comfortable with new smart thermostat vs previous thermostat	43%[b]	61%[d]	42%	59%[c]	70%	57%	24%	57%[g]	35%[j]	45%
Use auto-away feature (to setback thermostat when sensor does not register activity)	33%[b]	29%[d]	29%	13%[c]	36%	42%[h]	30%	11%[g]	17%[j]	2%
Use the smart thermostat to schedule the HVAC system fan	14%[b]	14%[d]	10%	6%[c]	12%	22%[h]	12%	5%[g]	3%	2%

8.12.4 Demand response program participation

Table 8-31 summarizes customer responses related to demand response program participation by program and dwelling type.

Table 8-31. Detailed results – Customer interest in DR programs, PY2020

Program type	Rebate	Rebate	DI	DI	Rebate	Rebate	DI	DI	DI	DI
Dwelling type	SF	SF	SF	SF	MF	MF	MF	MF	MH	MH
Participation status	NP	P	NP	P	NP	P	NP	P	NP	P
Sample size – n	4,363	2,818	2,650	559	85	102	486	131	267	235
Group notation / Demand Response	a	b	C	d	e	f	g	h	i	j
Interested or already enrolled in demand response	6%[b]	7%[d]	5%	9%[c]	5%	9%	8%	10%[g]	4%	4%
Pathways to Participation in Demand Response										
	(n=1752)	(n=1525)	(n=1014)	(n=242)	(n=35)	(n=71)	(n=196)	(n=40)	(n=88)	(n=69)
Would stay in program and during program events, would allow the program to automatically adjust thermostat set points	23%[b]	33%	27%	26%[c]	36%	36%[h]	28%	27%	25%	25%
Would stay in the program, and during program events, would override any adjustments, if it was inconvenient	45%[b]	50%	43%	39%[c]	43%	42%	42%	45%	45%[j]	36%
Would not agree to participate and would opt-out of the program if auto-enrolled	6%[b]	5%	3%	9%[c]	0%	9%	8%	7%	2%	6%
Discouragement from Participation in Demand Response										
	(n=280)	(n=209)	(n=159)	(n=48)	(n=3)	(n=10)	(n=34)	(n=12)	(n=14)	(n=10)
Don't know enough about it	26%	27%[d]	28%	36%[c]	0%	31%	27%	17%	6%	0%
Too complicated	5%[b]	14%	4%	12%[c]	0%	10%	2%	0%	15%	11%
Would not let anyone access their household appliances or data due to privacy and security concerns	51%[b]	52%[d]	56%	31%[c]	29%	50%	41%	66%[g]	54%	44%
Concerns that program will compromise comfort of their home	33%	33%[d]	33%	45%[c]	0%	30%	31%	39%	31%[j]	56%
Insufficient incentives	9%[b]	22%	11%	20%[c]	0%	40%	13%	5%	13%	0%
Currently not satisfied with their utility and therefore would not consider this	3%	4%	3%	4%	0%	10%	2%	12%	0%	0%
Do not use a lot of heating/cooling in the home	17%[b]	15%[d]	17%	10%[c]	6%	0%	29%	5%	16%	26%

8.13 Appendix M: Surveys

8.13.1 Occupant surveys – Program participants and non-participants

8.13.1.1 Program participant survey

Participant survey instruments used in the evaluation are included as pdf attachments.

8.13.1.2 Non-participant survey

Non-participant survey instruments used in the evaluation are included as pdf attachments.

8.13.2 Property manager survey

Property manager survey instruments used in the evaluation are included as pdf attachments.

8.14 Appendix N: Calibrated electric and gas consumption profiles

This section provides calibrated annual energy consumption values used in engineering simulation models. These values were the sources of simulated measure savings used to allocate whole-home savings. Participants NAC values are presented along with the calibrated energy consumption values and indicate that the calibrated values used in simulation models are reasonable. Figure 8-10 provides NAC and calibrated annual electricity consumption per home for each dwelling type and climate zone.

Figure 8-10. NAC and calibrated annual electricity consumption per home by dwelling type and climate zone

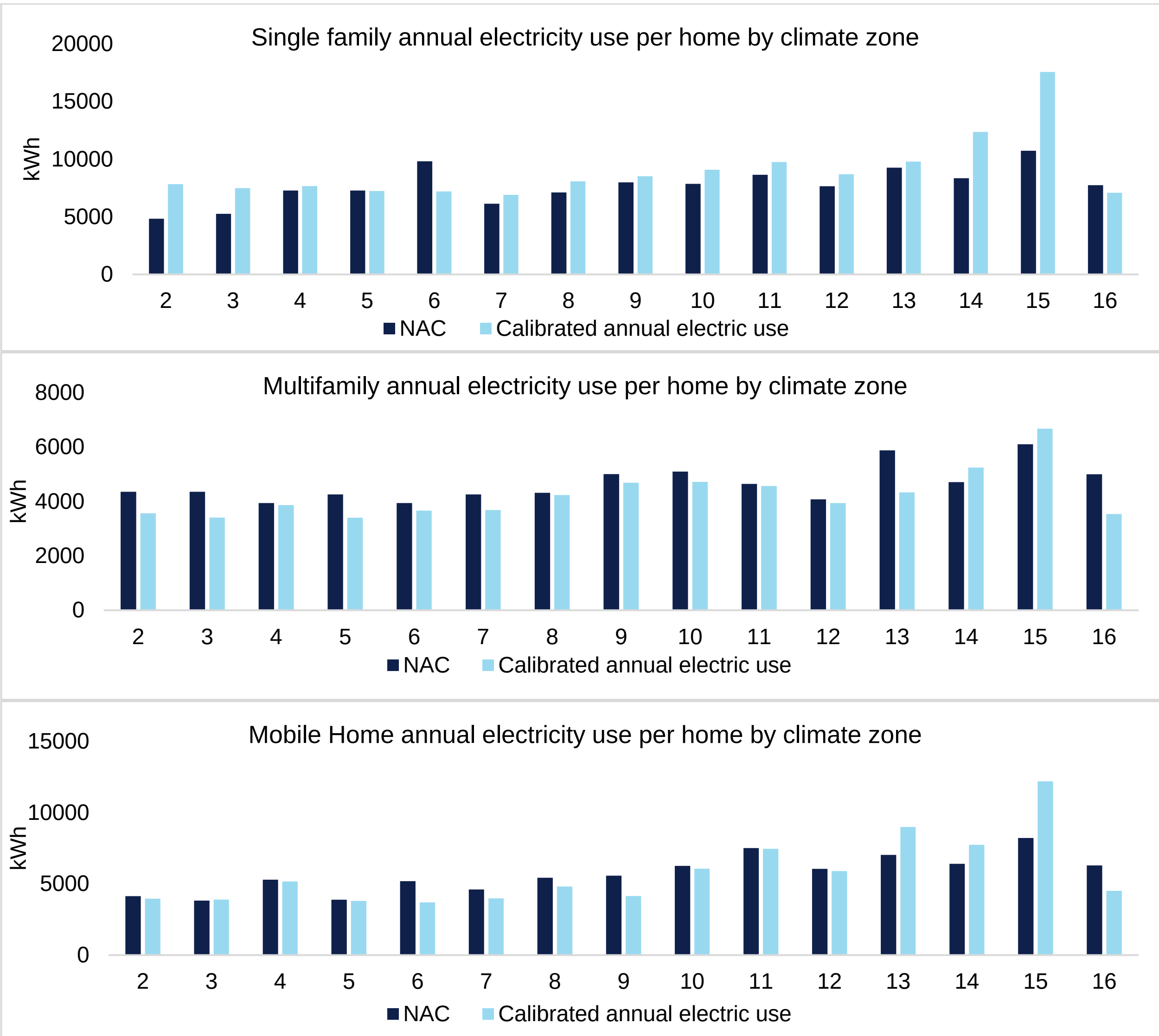
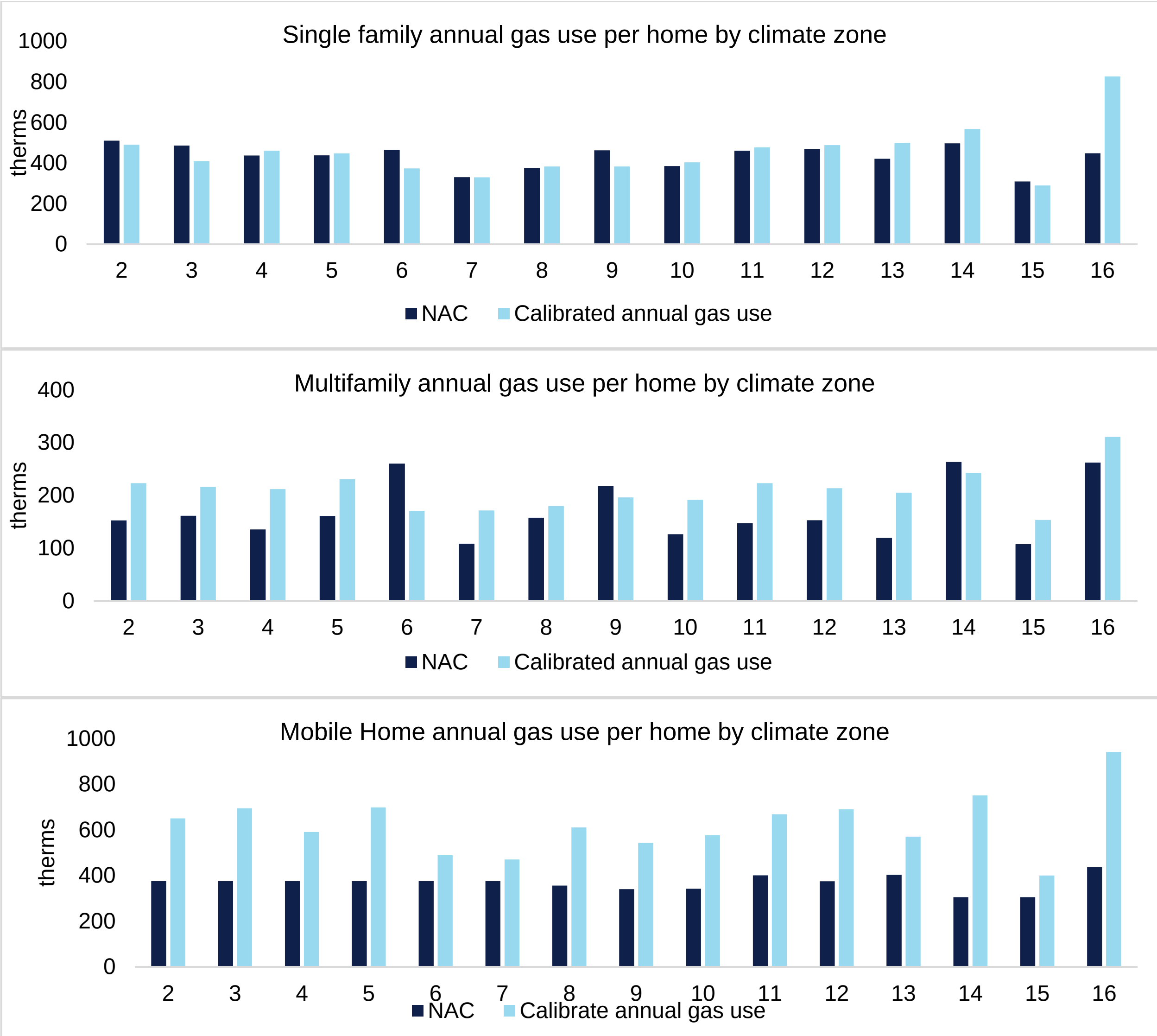


Figure 8-11. NAC and calibrated annual gas consumption per home by dwelling type and climate zone



8.15 Appendix O: Response to comments

Comment #	Commenter	Page (as shown in Word document footer)	Comment	Response
1	PG&E	Overarching	PG&E commends the evaluation team for a well-written and thorough draft report. PG&E appreciates the level of content detail provided throughout, such as sample design, methodological detail, explanations of results, recommendations and supporting data to take action on recommendation, and the application of IESR tables. The draft report reflects best practices in technical report writing.	Thank you. We appreciate the feedback. DNV strives to follow best practices and present evaluation results and insights based on these.
2	PG&E	Overarching	PG&E commends the evaluation team for the various tables (e.g., Table 5-4 and others) that showed comparisons to previous program years. PG&E appreciates the ability to readily see year-over-year trends and comparisons to inform its thinking towards the measures.	Thank you. We agree that looking at year-over-year evaluation results provides important context to current evaluation results and thus provides holistic measure/program related insights.
3	PG&E	Overarching	Overall, per-participant savings impacts appear to be quite small. For example, the report stated that for the rebate program smart thermostats, on average, "electric savings are 1% and gas savings are 0.5% of annual consumption." Assuming a similar finding for direct install programs, this impact is a small effect to detect at the whole-house level, more so when disaggregating to the measure level, all within potentially a large amount of noise (e.g., the impacts of COVID-19 on consumption). Generally speaking, confidence in the results is largely dependent on the quality of the matched control groups. Given the overall methodology used to estimate savings, can the evaluation team provide its thoughts on how robust the total savings estimates are? How reliable and accurate are the results, so that PAs can use the results to make informed program decisions?	The methods applied for this evaluation represent the best practice approach for these kinds of measures. While the percentage of savings out of overall consumption is small, data from large numbers of customers support results with sufficient precision. In addition, savings demonstrate consistency across years. Also, rebate results include an adjustment designed to address the possibility of differential trends between treatment and comparison groups. All of these aspects of the evaluation indicate these results are robust. While the presence of COVID-19 may increase noise, more importantly, the report recognizes that this undermines the optimizing potential of SCTs. Google indicated that Nest's Home Away run-time reductions decreased by 75%. This represents a downward pressure on savings that counteracts the possibility of increased savings due to the standard availability of opt-in thermostat optimization. This further supports ex-post evaluation results that are consistent with prior year results despite the presence of thermostat optimization.
4	PG&E	12	PG&E commends the evaluation team for acknowledging the limitations of using engineering models to support disaggregating total savings estimates in direct-install measures. Is it correct that the evaluation team used billing analysis to estimate total savings per home? Then it used engineering models to allocate total savings to individual measures, when multiple measures were implemented? Can the evaluation team share what other approaches it considered, and/or what approaches it may consider for future evaluations, in order to improve the certainty in the allocation of total savings?	This is correct. DNV first estimated whole home savings and then used engineering estimated savings to apportion whole home savings to the individual measure savings. For this evaluation, DNV explored estimating measure savings based on cases where measures were installed in sufficient quantities alone to understand what the measure can deliver without confounding interactive effects due to multiple measures. We undertook this analysis for smart thermostats where the data permitted it as a sensitivity check. While we explored conducting a similar analysis for the other residential HVAC measures evaluated, there was insufficient data to support this approach in PY2020. In future evaluations, DNV will consider: 1. additional statistical model-based measure savings by including data from homes that install a limited combination of measures; as an example, DNV will explore estimating models for homes that only install two measures. 2. using panel data models, which include data from participants and matches over time, as the basis of measure level savings. DNV will also explore
5	PG&E	45	It was noted that "installation patterns of electric measures for multifamily indicate unusual spikes in March 2020 and relative high installations in April 2020 compared to the rest of the summer months in that year." Can the evaluation team share any details with the PAs, so that each PA can look into possible explanations for this pattern?	DNV examined the monthly installations by PA and found that PG&E contributed to the March 2020 spike noted in DNV's report. DNV contacted PG&E about this spike and learned that the installation anomaly occurred due to a contracting issue, which resulted in an unusually high number of installations in that

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				month. PG&E indicated that delays in a contract renewal resulted in backlogged work that required the vendor to ramp up its energy efficiency activity. Edits made to the Executive Summary and Section 6.2 to reflect this.
6	PG&E	49-50	Can the evaluation team summarize its explanation(s) for the large differences in Gross Realization Rates (GRRs) for Rebate versus Direct Install delivery channels?	Electric GRR for rebated SCTs was higher at 71% than that for DI SCTs at 6% in PY2020. This is due to the combination of lower claimed electric savings for rebated SCTs (at 114 kWh) compared to claimed electric savings for DI SCTs (at 179 kWh) and the higher evaluated electric savings for rebated SCTs (at 81 kWh) compared to electric savings for DI SCTs (at 11 kWh). The primary contributor to the relatively low DI SCT evaluated electric savings is the observed low savings for MF installations. On the other hand, gas GRR for rebated SCTs was lower than that for DI SCTs in PY2020, primarily due to notable gas savings for DI SCTs in this program year. As we noted in comment #9, this could be due to the location of where SCTs were installed in PY2020 compared to PY2019 and a possible effect of thermostat optimization that was increasingly prevalent in PY2020.
7	PG&E	58	The evaluation team recommend to 'continue to adjust ex-ante savings for other measures similarly, particularly for those with fairly stable savings patterns from past evaluation'. PG&E questions this recommendation, in particular adjusting smart thermostat savings downward. PY 2020 can be viewed as an anomaly, in terms of energy consumption as well as the differential impact of COVID-19 among customers (e.g., rebate versus direct-install participants). Can the evaluation team share its thoughts on how to best apply PY 2020 findings to adjust ex-ante parameters appropriately?	The report notes that ex-ante savings estimates for rebated smart thermostats were adjusted downwards, which resulted in relatively higher GRRs for this measure in PY2020 compared to PY2019 and PY2018 evaluations. This past adjustment to rebated smart thermostat ex-ante savings estimates was made based on evaluation results prior to COVID-19 impacts. The recommendation stemming from this result is that ex-ante savings should be similarly adjusted for measures with fairly stable patterns based on past evaluations. The residual impact of the pandemic will likely result in changed occupancy characteristics for a significant number of households (for example: increased occupancy during the day due to work from home options) which consequently could impact savings potential for these measures that are based on a pre-pandemic paradigm. The ex-ante team is working to incorporate findings from PY2018 and PY2019 with PY2020 evaluation results, in its recommended ex-ante savings updates.
8	PG&E	58	In the PY 2019 evaluation cycle, the evaluation team had recommended to 'review the potential for fan control measures to interfere with savings opportunities from smart thermostats.' Based on the PY 2020 impact evaluation, can the evaluation team offer additional guidance on this potential for interference and the need to restrict smart thermostat installations?	We support the submission and review of additional workpapers or revisions of existing fan control workpapers that demonstrate additional heating, cooling or fan energy savings. Greenfan's Intertek has researched some of the interactive effects between fan controllers and smart thermostats. While the PY2020 impact evaluation report does not include a recommendation to review the interaction between these measures, DNV supports this submission for stakeholder review to help establish the nature of the interactive effects between these two measures. DNV notes that across both the PY2019 and PY2020 evaluations, these measures did not achieve claimed savings in combination or in isolation. We do not see a need to recommend an explicit measure combination restriction but rather focus on combinations of measures that save more when evaluated.

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9	PG&E	58	Can the evaluation team explain why it saw gas savings in PY 2020 when it did not see it in previous program years?	As noted in the report recommendations, since these results paint a mixed picture, DNV recommends additional study to examine the consistency and stability of the gas savings potential for smart thermostats. In PY2019, most direct install smart thermostat installations were in climate zone 10, which received 43% of the installations. In PY2020, by contrast, climate zones 10 and 13 received 27% of the installations each. Since climate zone 13 has greater heating needs than climate zone 10, the additional heating load and the consequent opportunity for heating savings could be one possible reason for the difference between smart thermostat gas savings in the two program years. It is also possible that thermostat optimization, which was not in full effect in PY2019 but became more widely available in PY2020, has contributed to the gas savings observed in the PY2020 evaluation. We have updated the report to include a footnote with this explanation.
10	SDG&E	5,8,14,18,47, 48,49,50, & 73	As stated on page 5 and similarly on page 14, "Estimate the electric and gas savings associated with PY2020 installations of smart thermostats, fan motor replacement, fan motor controls, and duct testing and sealing." However on page 8, Table 1-2 Total residential HVAC gas savings, PY2020 - omits gas savings for fan motor control. Please explain if the DID model and whole home savings considered potential gas savings for fan motor control and the reasons why it was not considered and omitted in the draft report.	There were no gas savings claims for fan motor controls in PY2020, which is why DNV did not evaluate gas savings for this measure. There were gas dissavings reported for fan motor replacements. As we noted on page 43 of the report, we estimated gas savings with and without fan motor replacements and did not find a significant difference. Since the data indicated little evidence of gas savings penalties, we did not consider gas penalties from motors in our evaluated results.
11	SDG&E	Overarching; Appendix 8.1 & 8.2	SDG&E was unable to find in the report the breakdown of each PA's evaluated figures in the original version of the draft study. SDG&E asked for clarity during the webinar and DNV would address to provide it in further updates, which DNV had provided by 4/5/22. SDG&E is appreciative that DNV staff was able to address comments earlier than the comment deadline period.	Thank you for bringing this to our attention. The ATR appendices are now included.
12	Google	Overarching	**Pandemic Impact on PY2020 Estimated SCT Savings:** The overarching issue with the draft PY 2020 report is that the study is trying to estimate the savings from SCTs while a pandemic dramatically affects society. SCT savings are largely derived from using more efficient set points, especially when the home is not occupied. At Nest, we observed a major reduction in the time that thermostats spent at "away" temperatures as the pandemic hit in March 2020. Even if the PY 2020 evaluation accurately estimated first year savings, the results would represent the SCT savings under specific pandemic conditions, rather than over their expected useful lifetimes. Given the impact of the pandemic, the PY 2020 report should not be used as the basis of estimating savings into the future.	PY2020 evaluation results will not be the sole basis of any adjustments to ex-ante savings estimates. The ex-ante team is working to incorporate findings from PY2018 and PY2019 with PY2020 evaluation results in its recommended ex-ante savings updates that will be the basis for future savings claims for this measure. While the pandemic resulted in abrupt and significant changes in household occupancy patterns, there will not be a full return to a pre-pandemic paradigm due to significantly sized customer segments continuing to work from home partially or fully. Hence evaluation results from PY2020 onwards could represent the start of a transition period to a new paradigm. Periodic evaluation to track savings and adjustments to ex-ante estimates until savings stabilize will be needed. Furthermore, given the product is likely to continue evolving due to software updates that aim to optimize its performance post-installation, the savings potential for this product will be dynamic further necessitating periodic evaluation and continued adjustment to ex-ante savings.
13	Google	45	**Issues with Multifamily Direct Install Installation Timing:** On page 45, the report discusses a huge unexplained spike in reported multifamily direct install (MF DI) installations right at the start of the pandemic in March 2020, stating: “While we don’t know what caused this spike, its coincidence with the onset of the pandemic suggests there may have been something very different about these	DNV investigated and identified PG&E as the source of the noted installation spike. PG&E clarified that the spike was due to a delay in a contract renewal, which resulted in backlogged work that required the vendor to ramp up its energy efficiency activity.

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			installations. There could have been a difference in the installation process with a large volume installed in a short time or else some recording issues of installation dates, which could substantially degrade the savings estimation." Given that the MF DI segment had the largest SCT savings in the PY 2019 report but now has the lowest in the PY 2020 report, this installation reporting anomaly requires further investigation.	Edits made to the Executive Summary and Section 6.2 to reflect this.
14	Google	Overarching	**Continued Issues with Selection Bias and Savings Allocations:** We continue to have many of the same concerns that we shared in prior evaluation comments, namely that the expected savings from SCTs are fairly small compared to the likely biases from selection effects, and that savings were under-allocated to thermostats based on questionable engineering assumptions (for additional comments, see Google Nest Comments on Impact Evaluation of Smart Thermostats Draft Residential Sector- PY 2019 3/23/2021). **a) Selection Bias**: The PY 2020 report showed that 6% of rebate participants added EV charging during the analysis period which, by itself, can be expected to increase electricity use by more than the total claimed savings for the SCTs for the program – at 2500 kWh/yr for EV charging, the 6% difference averages 150 kWh/customer while claimed savings averaged 114 kWh. In addition to EVs, participants reported net increases of 5% in household size, 4% in living area, and 2% extra refrigerators. When added to the EV impacts, these biases can be expected to increase the electricity use of the rebate population by more than twice as much as the claimed SCT savings. DNV did adjust the reported savings based on observed changes in baseload usage, which is a step in the right direction. However the adjustment is largely subjective and different choices could have led to dramatically different savings.	DNV made the adjustments to smart thermostat savings referred to in the comment because we found the energy consumption trend for this group of participants to be higher than for matched comparison homes. Absent any additional information, the use of trend in the baseload portion of energy consumption, which is not targeted by HVAC measures including SCTs, is a sound basis for such an adjustment. This baseload trend adjustment is grounded in data that reflects measured energy consumption for the population of participants than are self-reported responses from a smaller subset. While selection issues are likely present, given the opt-in design of the programs that deliver SCTs, DNV has used the best available and widely accepted methods to evaluate the impact of this measure. Additionally, given the higher level of self-reported energy using actions reported among direct install participants compared to matched non-participants, DNV investigated baseload trend differences to determine if the self-reported energy using action differences are supported by the data. The changes in energy using actions listed in the comment (including the addition of EVs, increases in household size and living space, and the addition of refrigerators) are end-uses that affect baseload. Any differences in energy using actions between participants and their matches will show in baseload differences between the two groups. Our investigation did not find such a difference for direct install participants. Thus, as we noted in the report, conditions that are conjectured to contribute to the differential trend for rebate don't apply to direct install programs.
15	Google	Overarching	**b) Savings Allocation Across Measures:** For the Direct Install programs, whole home savings were allocated to measures based on engineering estimates. These estimates, which allocated 87% of savings to measures other than SCTs, are based on many highly questionable assumptions. For example, the "engineering" modeling estimated SCT savings in CZ-13 at just 62 kWh, which is only 2% of cooling use. The modeling of SCTs assumes that program participants would have the same thermostat settings as the average household estimated in RASS. Very small differences between SCT participants and the RASS population could lead to very large differences in estimated savings. For some other measures, the engineering models employ optimistic baseline assumptions that lead to inflated savings. The net result is that the engineering modeling is likely to result in significant misallocations.	The engineering simulation modeling relies on measure workpaper methods, CPUC evaluation data, and RASS data. The evaluation team did not have data on setpoints pre-and post-smart thermostat installation for the engineering simulation modeling. In the absence of such data, the evaluation team leveraged RASS data for baseline thermostat setpoints and developed setpoint setbacks that targeted recent evaluation savings outcomes for the smart thermostat. Overall, the evaluation found limited household-level savings to allocate among the measures, all of which fell short of claimed savings.
16	SoCalGas	15, 16	Table 2-1 SCG RES LADWP HVAC- SCG 3836. This program is part of LADWP's HVAC Optimization program which is a no-cost direct install program where an eligible customer gets a no-cost Nest thermostat and an A/C tune up. SoCalGas would like to know if this was included as part of direct install or rebate category.	SCG3836 was evaluated as a direct install program.
17	SoCalGas	31	**3.4 Program attribution** - DNV's method of calculating NTGRs assessed three dimensions of free ridership: timing, efficiency (when applicable to the measure), and (for multifamily property	Thank you. We will incorporate DAC/HTR dimension to program attribution, where applicable, in future evaluations.

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			managers) quantity. SoCalGas believes that installing for DAC/HTR customer is another attribution. This for example happened for the CLEO program and as another dimension could be added to the existing evaluation, otherwise SoCalGas suggest that this dimension should be used in the next evaluations	
18	SoCalGas		**Recommendation 5.1.2 Commercial boilers, distributor role.** SoCalGas agrees with the comments and understands that retailers / distributors can be critical ambassadors for the SoCalGas' rebate programs and can play a pivotal role in informing customers about technical considerations when they are purchasing new equipment. SCG EE Programs have worked with large box retailers and distributors in the past and continue to strive to engage them when possible.	The Residential HVAC PY2020 Impact Evaluation report does not include an evaluation of commercial boilers. Evaluation results for the following measures are presented in this report: Smart thermostats, fan motor controls, fan motor replacement, and duct testing and sealing.
19	SoCalGas	25	**Smart thermostat for rebate vs direct install, section 3.2 page 25** In this section, the gross saving methodology is different for rebate and direct installed smart thermostat programs. In the report it is discussed that, in rebate there is only one measure and in direct install programs multiple measures installed and since DNV used different methods and adjustments for these two cases, their gross savings are different. It looks like that the customers of two groups (rebate and direct installed) who bought the same smart thermostat, both installed the thermostats with the same recommendations of manufacturer, are getting different gross saving and therefore different GRR and NRR, only because they participated in different programs. SoCalGas disagrees with this methodology, as gross savings are the same, regardless of delivery method. The report should be updated to reflect the same gross savings and GRR on rebate as it was given to direct install programs.	The interactive effects when multiple measures are installed result in the same measure achieving different savings. The savings are not additive across measures. DNV stands behind the methodology employed to estimate savings for measures when installed in isolation or via rebate programs versus when installed in combination with other measures.
20	SCE	7	**Table 1-1. Total residential HVAC electric savings, PY2020.** Significant variations and inconsistency on PY2020 GRR between DI and Rebate for smart thermostat compared to other program years suggest that measure savings estimation methods (particularly for DI) including engineering estimates and assumptions may need to be re-evaluated. Hence, updates to (deemed) measure packages and/or measure characterization on the smart thermostat and/or other evaluated technologies using PY2020 impact evaluation results are NOT recommended.	PY2020 evaluation results will not be the sole basis of any adjustments to ex-ante savings estimates. The ex-ante team is working to incorporate findings from PY2018 and PY2019 with PY2020 evaluation results in its recommended ex-ante savings updates that will be the basis for future savings claims.
21	SCE	8	**Table 1-2. Total residential HVAC gas savings, PY2020**. Significant variations on PY2020 evaluated gas savings for smart thermostat compared to all previous impact evaluations and/or EM&V studies, suggest that this impact evaluation used abnormal data and/or conditions that are not representative of “standards” program conditions. Hence, updates to (deemed) measure packages and/or measure characterization on the smart thermostat and other residential measures using PY2020 impact evaluation results are NOT recommended.	See response to comment #20.
22	SCE	23	**Table 3-2. Smart Thermostat customer counts used in the evaluation.** How many solar (net-meter) accounts were in the dataset (by PAs)? How many accounts did not have sufficient data? Can these accounts be flagged and returned to SCE or PAs to review? Additionally, why can't there be any analysis with the net-metered accounts? Evaluation with and without net-metered accounts would be very insightful (considering that the solar market is expanding).	Table 3-2 in the report provides the count of households for which data was received ("Customers for whom some data was received" row) and those that were not net-metered ("Customers with data and not net-metered" row) by PA and fuel. The difference between the two provides the number of households that were net-metered. Based on this difference, 18% of PG&E, 32% of SDG&E, and 25% of SCE participants were net-metered during the analysis period. Since we are not able to include net-metered customers in the analysis, we did not investigate how many net-metered customers have sufficient data for analysis. The attrition or move-out levels for the remaining households can serve as an indicator of the same for net-metered households.

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				While we agree an analysis that includes net-metered accounts would be useful, DNV is unable to include data from net-metered accounts in the analysis because we do not have full visibility into the total energy consumption of these households. PAs do not have complete data on all net-metered customers' on-site solar production that would provide full energy consumption information for such households. Without such data, it is not possible to determine changes in energy consumption due to energy efficiency installations. DNV is exploring ways to estimate solar production to include such households in future studies.
23	SCE	6	**COVID-19 implications for the PY2020 Residential HVAC Evaluation (Page 6).** The evaluator included data outside the specific program year being evaluated – "In order to have a more robust basis for the evaluation, we augmented the data used in our analysis with participants from the second half of 2019." The use of data that does not fully correlate with the evaluated program year in question (PY2020), (perhaps to support both treatment and non-treatment groups), may have resulted on an increase of uncertainty on the study's finding particularly due to "pandemic" effects.	The use of additional data increases the number of observations available for the analysis, which would actually reduce standard errors and hence uncertainty of estimated effects. While it is true that the effects of COVID-19 are felt differently by different installation cohorts, most of the participants we included in our study have post periods that include consumption during months affected by COVID-19. We discuss the effect of COVID-19 on the analysis in Section 6.6 of the report. As we indicate in that section, the current evaluation uses data from participants that installed program measures from May 2019 to December 2020. All cohorts have post-period consumption that is affected by COVID-19 to differing degrees. Starting with April 2020 participants, increasing portions of pre-period consumption were also affected by COVID-19. Thus, households PY2019 included in the analysis are also impacted by COVID-19 as are PY2020 participating households.
24	SCE	6	The study further acknowledges that "For the smart thermostat, changes in customer habits due to COVID-19 could undermine the effectiveness of some of the optimization functions of the measure. For example, optimizing setpoints may be more difficult when occupants are home all the time and thus reducing opportunities for setbacks that could help achieve savings" … the study further suggests that… "The additional variability of the pandemic period injects a degree of variability into results (potential bias in either direction) that will not necessarily be reflected in precision estimates but may explain anomalous results"; hence, it is recommended (given the uncertainty of the findings) for Commission not to require related measure packages (including the smart thermostat measure package) to be updated with PY2020 IE findings.	PY2020 evaluation results will not be the sole basis of any adjustments to ex-ante savings estimates. The ex-ante team is working to incorporate findings from PY2018 and PY2019 with PY2020 evaluation results in its recommended ex-ante savings updates that will be the basis for future savings claims.
25	SCE		**Figure 1-3. Direct Install average hourly savings for homes without smart thermostat installations:** It is not clear if the presented hourly savings profiles in figure are representative of statewide residential conditions and/or for a representative Climate zone. Measure savings methodology should leverage single dedicated profiles specific to each climate zone, building type, and delivery type.	Dedicated measure-level profiles specific to each climate zone, building type, and delivery type are clearly a goal but are currently not feasible given population numbers, multiple measures (for DI), and rebate participant self-selection. The large numbers that make it possible to get robust estimates across the state are not available at this level of granularity. We continue to look for methods that will allow us to provide load shapes at this more granular level.
26	SCE		**1.6 Recommendations.** The impact evaluation missed to investigate and/or continue to evaluate measure savings contributions and/or competing effects for bundled measures particularly when including both smart thermostat and fan control. This is important given PY2019 recommendations indicating that – "Low electricity savings for smart thermostats possibly reflect competing effects of fan controls and smart thermostats, both of which are capable of delaying fan turn-off. Similar to what fan	SCE's response to recommendations (RTR) to the PY2019 smart thermostat report was that it would evaluate future workpaper updates to consider restricting the installation of fan controls for implementations that include smart thermostats. It also stated that future impact evaluations should determine measure savings for DI programs that install SCTs and fan controls together. SDG&E's RTR to the PY2019 smart thermostat report states that

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			controls do, smart thermostats have a feature that uses the fan to spread remaining cool air in the HVAC coils through a home after switching off the air-conditioner compressor."	SCE is the PA lead for the workpaper update and had proposed restrictions for PA DI programs to exclude fan control technologies from being installed with smart thermostats. DNV's PY2020 evaluation found smart thermostats continue to deliver lower than expected savings when installed alone or in combination with other measures including fan controls. We did not have a sufficient number of installations in PY2020 to investigate fan control savings when installed alone. Hence, we had an insufficient basis for an analogous analysis for fan controls to that presented in the PY2019 evaluation.
27	SCE		**3.2 Gross savings.** The Study failed to include and make publicly available detail documentation on evaluated measure savings for all evaluated EE measures including measure savings (kWh/therms) per CZ (for all 16 California Climate Zones), Residential Building types (SFM, MFM, DMo), and delivery type (DI, Rebate). This information would have been very useful for better understanding measure savings characterization including dependency and sensitivity of savings due to climate variations – e.g., cooling degree and heating degree hours.	These details are now included in Appendix G, section 8.7.4 of the report.
28	SCE	13	**Data quality.** Considering that data quality is an issue and creates caveats around the results, why aren't there any proper recommendations on how PA can improve the data quality? Can PAs/ED/DNV work together to identify and address some of the pain points and mitigate the potential data issue for the future evaluations?	Data issues range from what is being captured by program tracking data to the completeness and quality of CIS data The data related findings regarding the lack of clarity on contact information for the decision-makers in the case of DI programs and the lack of a crosswalk that enables mapping SoCalGas customers to their electric PA accounts resulted in the following recommendations respectively for PAs: 1. Prescribe program tracking data requirements that include capturing these specifics 2. Facilitate cross PA identification of customer account IDs for program participants residing in territories served by different electric and gas PAs. More broadly, DNV has also strived to assist the PAs in bridging data quality issues by sharing cleaned customer email addresses back with the PA so that PAs can update their CIS data for these customers. DNV will continue to work with ED and the PAs to address this important issue.
29	Verified	Overarching	VERIFIED thanks the CPUC Energy Division and DNV for the opportunity to provide public review and comment of the Draft Impact Evaluation of Residential HVAC Measures – Program Year PY2020.	Thank you. We appreciate the review and stakeholder feedback.
30	Verified	Overarching	The draft report, comment, and final report process provides limited opportunities for comments to improve the final report. Providing a draft presentation and allowing comments to be submitted before the presentation will allow at least one more opportunity to consider comments to improve the final report.	The standard process is to present evaluation results based on the draft report to stakeholders and then update the report, as needed, based on edits/comments to address stakeholder feedback.
31	Verified	5	There are two Fan Control (FC) measures in the 2020 residential HVAC programs: 1) 6,646 FC measures that only save cooling energy, and 2) 3,600 Efficient Fan Control (EFC) measures that save cooling and heating energy. EFC heating savings should be included in the evaluation, since EFC workpapers providing heating savings are available. EFC workpapers were provided to PG&E, SoCalGas, and SDG&E in 2012. EFC workpapers were also provided to IOUs in 2016-2018. The 2012 EFC workpaper was submitted and approved by the CPUC in 2012. See WPSDGEREHC002. California	WPSDGEREHC0024 expired after PY2019 with the consolidation of fan control workpapers. All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there were fan control measure claims outside of programs we looked at, they

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			HVAC Upgrade: Efficient Fan Controller (EFC) – Residential. Intertek test data for heating savings have been available since 2015. See Intertek. 2015. Intertek Performance Evaluation of an Efficient Fan Controller (EFC) Installed on Split and Packaged Air Conditioners with Gas Furnaces. Intertek No. G101756555. https://nw.ax/Ph.	were not identified in tracking data used in the study.
32	Verified	7,8	Fan Motor Replacement (FMR) and Duct Test Seal (DTS) savings are inconsistent with Intertek test data discussed in Comment #2 and Comment #3. High-external Static Pressure (HSP) can impact FMR savings. Standby power can also impact FMR savings. FMR measures are constant torque Brushless Permanent-magnet Motors (BPM). The BPM uses more standby power than standard Permanent Split Capacitance (PSC) motors (e.g., 4W). There are two Fan Control (FC) measures in the 2020 HVAC programs: 1) 6,646 FC measures only save cooling, and 2) 3,600 EFC measures that save cooling and heating energy. EFC heating savings should be included in the evaluation, since EFC workpapers providing heating savings are available. Comment #4 addresses this issue since EFC savings impacts the assignment of kWh and therm savings for other measures. Table 3-6 (pp. 23-24 of the 2021 DNV Impact Evaluation Report Residential HVAC Sector – PY 2019 provides the following sources for simulation inputs. (1) Fan Controls (FC) – savings based on cooling EIR adjustment with efficient EIR = 0.87025 * baseline EIR (13% savings). (2) Fan Motor Replacement (FMR) – Supply kW/flow adjustment 0.00065 to 0.0004 kW/cfm and Supply delta-T adjustment of 2.054 F to 1.012F. (3) Duct Testing and Sealing (DTS) – based on Duct Air Loss % reduction (30.42% to 15% for SFM/MFM, 33.52% to 15% for DMO). (4) Smart Communicating Thermostat (SCT) – various heating and cooling setpoint schedules such that efficient schedule produces 2% to 3% cooling/heating savings when only setpoint schedule change is applied.	DNV followed the available statewide workpaper (SWHC038-01) methods and baseline assumptions in its simulation modeling of fan motor replacements. DNV also included field data collected during PY2018 as inputs for the measure case performance. In addition, as we indicated in response to comment #31, DNV evaluated fan control measure savings whose claims were based on statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology, and the measures under this workpaper afforded no claimable therm savings. If there were fan control measure claims outside of programs we looked at, the tracking data we used for the evaluation did not identify them.
33	Verified	7,8	Comment #3: - Fan Motor Replacement (FMR) assumptions and savings FMR savings and simulation inputs are inconsistent with Intertek tests of BPM CT motors which are less efficient than BPM constant-airflow motors because they are designed to have a narrower speed range and higher turndown ratio to retrofit PSC motors. Airflow decreases and power increases as External Static Pressure (ESP) increases. ESP is the difference between air pressure on fan outlet minus air pressure on fan inlet. BPM standby power is 1.4W compared to the PSC motor or about 11.9 kWh/y-unit for the BPM. This might reduce FMR savings by 11.9 kWh/y-unit from 83.7 to 71.8 kWh/y-unit without considering other issues. Please refer to Intertek test data from 2011 of a 3-ton AC unit with standard PSC fan motor (Test 620A) versus a BPM installed on the same unit (Test 618A) with ESP of 173 Pascal (0.7 Inches Water Column IWC). Intertek tests were funded by the CPUC and managed by CPUC consultants. LBNL Report: Lutz, J., V. Franco, A. Lekov, G. Wong-Parodi. 2006. BPM Motors in Residential Gas Furnaces: What Are the Savings? Page 5. Lawrence Berkeley National Laboratory. ACEEE Summer Study. aceee.org/files/proceedings/2006/data/papers/SS06_Panel1_Paper17.pdf. Please see: Verified draft comments 2022 DNVGL HVAC study 20220408.pdf	The evaluation modeling approach for fan motor replacement and fan controller measures aligns with the approved workpapers. We agree that the measure package could be revisited in light of this citation of evidence for standby power, constant-torque vs. constant-airflow, and ESP. DNV advises the lead PA for fan motor replacements, CAL TF, and the CPUC reviewers to consider revising the fan motor replacement measure package given the information discussed in the referenced Intertek study.
34	Verified	7,8	DTS assumptions and savings. DNV Table 1-2 on page 8 provides a 125% gross realization rate for DTS indicating an incorrect assignment due to not including EFC heating savings based on no claims for fan control measures per footnote 27 on page 22 "There were no gas savings claims for fan controls." The draft DTS gross evaluated unit savings are 123.3 kWh/y or 2.85-times greater than the FC gross evaluated unit savings of 43.3 kWh/y-unit. Based on	DNV modeled savings-weighted changes in % duct leakage in combination with the other evaluated measures using eQUEST and following workpaper methodologies where possible. We have added details of these inputs to the final report. All evaluated fan control measure savings claims were made under statewide workpaper

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			DNV simulation inputs and Intertek test data, DTS savings should be 28% as shown in Figure 3 and regression Equation 5. Equation 5 yDTS = -1.2562*x + 1.01520. Where, y=DTS efficiency impact, and x = duct leakage. Equation 6 can be used to calculate DTS program savings with average pre and post DTS leakage (DyDTS). Equation 6 shows savings are 29% based on DNV assumptions. The average DTS savings should be based on the average DTS leakage reduction for the program, but the 2022 DNV HVAC study does not provide this information. Table 3-6 Sources for Simulation Inputs on page 23 of the 2021 DNV HVAC study provided Duct Air Loss percentage (%) reduction of 33.52% to 15% for DMO based on the workpaper WPSDGEREHC1067 and SWSV001-01. Assuming pre DTS leakage x0 = 33.52% and post DTS leakage x1 = 15%, then the DTS program savings are 28%. If the simulation inputs use 28% DTS savings and 13% FC savings, then the ratio of DTS to FC savings should be 2.15 and not 2.85 since both measures increase cooling capacity and reduce AC operation to save cooling energy. The EFC measure increases heating capacity like DTS with the same savings ratio. Therefore, the therm savings for DTS and EFC should have the same savings ratio.	SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in the tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update.
35	Verified	7	Alternate total residential gross evaluated HVAC kWh savings. alternate #1 gross evaluated HVAC kWh savings for PY 2020 by assigning gross evaluated savings of 48.4 kWh/y-unit to the FMR measure from Table 9 based on the Intertek laboratory test data, perfect installation, maintenance, and -11.9 kWh/y-unit of standby power compared to PSC motors which have zero standby power. Savings assigned to FMR might be 23 kWh/y-unit based on Intertek tests and HSP installation and maintenance factors per Table 10. Savings for FMR might be -10.7 kWh/y-unit based on field tests of actual BPM CT motors, standby power, and HSP maintenance factors shown in Table 11. The Fan Control (FC) and EFC measures have different savings since FC provides 1-minute shorter cooling fan-off delays and does not provide variable heating fan-off delays like the EFC. Based on the alternate savings assignment, 302,511 kWh/yr of FMR savings are reassigned to SCT, 60,576 kWh/yr of FMR savings are assigned to FC, and 46,591 kWh/yr of FMR savings are reassigned to 3,600 EFC measures. The reassignment of savings from FMR and DTS to SCT requires review to determine whether FMR standby power is included and how much savings should be assigned to DTS, FC, or EFC based on cooling UEC values which are not provided in the DNV study. The DTS to FC and EFC savings ratio of 2.3 is based on 123.3 kWh/y-unit for DTS divided by sum of FC savings without standby use (52.5 kWh/y-unit) times FC weight of 64.9% (6646/10246) plus EFC savings plus standby and heating fan energy (56.3+4.85+2.5 kWh/y-unit) times EFC weight of 35.1% (3600/10246). This reassignment includes EFC standby energy use and EFC fan heat, but does not include the FC standby use identified in Table 13. Table 14 provides 4.8% savings for SCT DI, 11% savings for FMR, 28% savings for DTS, 12.8% savings for FC, and 13.7% savings for EFC.	DNV's simulation modeling for fan motor replacement measures followed the available statewide workpaper (SWHC038-01) methods and baseline assumptions together with field-collected PY2018 evaluation inputs for the measure case performance. We agree that the measure package could be revisited in light of this citation of evidence for standby power, constant-torque vs. constant-airflow, and ESP. All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated through the transition to the EnergyPlus platform and heating system savings capability of logic-based controllers included in this measure update effort.
36	Verified	8	Four mobile home programs installed 3600 Efficient Fan Control (EFC) measures that provide a variable fan-off delay for heating and cooling. (1) PG&E – Direct Install for Manufactured and Mobile Homes - PGE21009. (2) SCE – Comprehensive Manufactured Homes - SCE-13-TP-001. (3) SCG – RES-Manufactured Mobile Home - SCG3765. (4) SDG&E – 3P-Res-Comprehensive Manufactured-Mobile Home - SDGE3279. Heating savings for 3600 EFC measures should be included in the impact evaluation report to properly report savings for SCT DTS measures. Estimated EFC savings of 17,814	All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system

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			therms or 4.9 therm/yr-unit are provided in Table 16 based on reassigning 59,814 therm savings from SCT to DTS and EFC measures. The EFC provides a 2 to 5-minute variable fan-off delay after gas furnace heating cycles to deliver more heating capacity based on laboratory tests performed by Intertek an AHRI-certified test facility used by USDOE. Intertek test data for the EFC are shown in Figure 4 and Table 15. EFC gas furnace savings range from 8.7 to 19.8%.	savings capability of logic-based controllers can be included as part of the measure savings update.
37	Verified	8	The DNV draft gross evaluated therm savings do not include heating savings for a quantity of 3,600 EFC measures that provide a variable fan-off delay of 2 to 5 minutes after each heating cycle. This omission impacts the assignment of therm energy savings for SCT and DTS measures. Unless evidence is provided in the AMI data, 59,814 therms from the SCT DI heating savings should be reassigned to DTS and EFC measures based on quantity of measures and the ratio of DTS-to-EFC EFC savings (i.e., 2.15=0.28/0.13). SCT DI unit therm savings are assumed to be same as SCT rebate unit savings of 2.26 therm/yr where the remainder is reassigned to DTS and EFC. Table 16 provides an alternate therm savings assignment based on reassigning 59,814 therms from SCT where 42,000 therms are assigned to DTS and 17814 therms are assigned to EFC.	All evaluated fan control measure savings claims were made under the statewide workpaper SWHC029-01 source. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update.
38	Verified	14	New systems do not “have built-in fan controllers.” Instead new systems have fixed fan-off delays from 30 to 120 seconds (57% have 60-second cooling and 90-second gas heating delays). Fixed fan-off delays waste energy by leaving 8.9 to 35% of available cooling or heating capacity undelivered. Fan controllers provide 2 to 6-minute variable fan-off delays to increase energy efficiency, comfort, and indoor air quality.	Per workpaper SCE17HC052.0, "the baseline air conditioning system cannot have built-in delay controller and/or device capable of delaying fan operation. Please note that some of the smart thermostats, if not all, already have the fan delay controller." However, we will modify the language in the report to differentiate the functionalities of built-in (native) or add-on equipment, and fixed fan-off delay versus variable fan-off delay controllers.
39	Verified	22	Four mobile home programs installed 3600 Efficient Fan Control (EFC) measures that provided a variable fan-off delay for cooling and heating: (1) PG&E – Direct Install for Manufactured and Mobile Homes - PGE21009; (2) SCE – Comprehensive Manufactured Homes - SCE-13-TP-001; (3) SCG – RES-Manufactured Mobile Home - SCG3765; and (4) SDG&E – 3P-Res-Comprehensive Manufactured-Mobile Home - SDGE3279. Heating savings for 3600 EFC measures should be included in the impact evaluation report to properly report savings for Smart Communicating Thermostats (SCT) and Duct Test Seal (DTS). Estimated EFC savings of 17,814 therms or 4.9 therm/yr-unit are provided in Table 16 based on reassigning 59,814 therm savings from SCT to DTS and EFC measures. There are 6646 fan control measures that do not provide a heating variable fan-off delay: (1) MCE - Single Family Direct Install Standalone - MCE08; (2) MCE - Multifamily Direct Install Standalone - MCE05 Multifamily; (3) PG&E - Enhance Time Delay Relay - PGE21008; (4) SCE - Multifamily Energy Efficiency Rebate Program - SCE-13-SW-001C; and 5) RES-LADWP HVAC - SCG3836 program.	SCG3765 did not install fan controls in PY2020 and the other PAs that installed fan controls in PY2020 did not claim heating/gas savings per the workpaper they used. We note, however, that SCG3765 did install fan controls that had gas savings claims in PY2019. All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update.
40	Verified	54	Fan control savings mechanisms do not overlap with smart thermostats. Ecobee provides a default 30-second fan-off delay, but the Ecobee delay is ineffective for HVAC systems with fixed fan-off delays of 30-to-120-seconds for cooling or heating. The Google smart thermostat Airwave option has been available since April 5, 2012, but Google has not provided any evidence of energy savings. Airwave is not a default setting. Airwave includes Early Air-conditioning Compressor Turn-off (EACT) which reduces cooling capacity and cooling efficiency causing comfort issues and more frequent less-efficient Air Conditioning (AC) cycles. Low cooling capacity and efficiency causes occupants to reduce cooling setpoints which increases energy	Per workpaper SCE17HC052.0, "the baseline air conditioning system cannot have built-in delay controller and/or device capable of delaying fan operation. Please note that some of the smart thermostats, if not all, already have the fan delay controller." However, we will modify the language in the report to differentiate the functionalities of built-in (native) or add-on equipment, and fixed fan-off delay versus variable fan-off delay controllers.

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			use. The Airwave delay is generally 1-minute or less, and most new HVAC systems provide a 1-minute fan-off delay. Smart thermostat fan-off delays are very short and not like fan controls which provide variable fan-off delays from 2 to 6 minutes based on the duration of the AC cycle. The EFC also provides variable fan-off delays of 2 to 5 minutes after each heating cycle.	
41	Verified	58	Fan controls were installed in many homes where DTS and fan motors were installed so fan controls may have contributed to electric savings from fan motor savings. The FMR measure is a BPM that may use 9W of standby power compared to PSC motors that only use 5W of standby power. Standby power might reduce FMR savings by -11.9 kWh/y-unit. High ESP of 50 Pascal from HVAC duct systems with more static pressure or dirty air filters will reduce or eliminate FMR savings. These issues need to be included in the analysis to avoid inadvertent errors which would unfairly reduce savings for other measures such as SCT, DTS, Fan Control, and EFC measures.	DNV's simulation modeling of fan motor replacement measures followed the available statewide workpaper (SWHC038-01) methods and baseline assumptions together with field-collected PY2018 evaluation inputs for the measure case performance. We agree that the measure package could be revisited in light of this citation of evidence for standby power, constant-torque vs. constant-airflow, and ESP.
42	Verified	58	The evaluation found no gas savings for SCT in the PY 2019 DI programs but Table 1-2 assigns 133,472 therms of gross savings for 32,592 SCT DI units or 4.1 therm/yr-unit. Some of these savings are from 3600 EFC measures that save heating energy and were installed in DI programs with smart thermostats. Comments provide evidence regarding 3600 EFC measures providing gas savings to reassign 42,000 therm savings from SCT to DTS to provide 9.2 therm/y-unit and reassign 17,814 therms from SCT to EFC DI to provide 4.9 therm/y-unit. Please correct include EFC gas savings.	To understand whether the estimated SCT gas savings are due to fan controls, DNV estimated gas savings for smart thermostats using data from homes that did not install any fan controls. We find gas savings for SCTs are higher for homes that installed SCTs without fan controls compared to homes that installed SCTs with fan control. For example, in multifamily homes, SCT savings with and without fan controls are 3 and 4 therms per unit per year, respectively. Thus, the claim that fan control gas savings are wrongly assigned to smart thermostats does not accord with this finding. It is possible that the location where smart thermostats were installed in PY2020 vs PY2019 (see the response to comment #9) and the wider availability of thermostat optimization could be driving the observed gas savings for SCTs in PY2020. Moreover, all evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there are fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update.
43	Verified	58	The efficient fan control measure provides cooling and gas heating savings verified by Intertek test data and field measurements. The EFC works with DTS and SCT measures to cost effectively increase cooling and heating savings. Please review assumptions for the FMR measure and assign more kWh savings to SCT, DTS, and FC measures in Table 1-1. Also, please consider increasing DTS therm savings and include EFC therm savings in Table 1-2.	All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there were fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update. The evaluation modeling approach for fan motor replacement and fan controller measures aligns with the approved workpapers. We agree that the measure package could be revisited in light of this

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				citation of evidence for standby power, constant-torque vs. constant-airflow, and ESP.
44	Verified	54	On page 54, DNV identified fan control as a necessary measure for “smart thermostat savings in single family and mobile home houses.” On page 7, DNV stated that “fan motor control delays turning off the fan motor at the end of an air conditioning or heating cycle to increase the HVAC system’s effectiveness by extracting the remaining cooling or heating potential.” Fan controls provide variable fan-off delays that are 4 to 12 times longer than smart thermostat delays to increase energy savings, comfort, and indoor air quality. Efficient fan control technology can be implemented on smart thermostats. We encourage the CPUC to set up workshops for smart thermostat and fan controller manufacturers to collaborate on how to incorporate fan delays, fan-on duration controls, and fault detection technologies into smart thermostats to increase energy savings, cost effectiveness, and customer satisfaction. Collaboration will help smart thermostats become a gateway for innovation and increased energy savings.	We encourage collaboration. For the development and revision of measure packages, Cal TF or CAAEEC could be potential organizers.
45	GreenFan		First, I’d like to thank the CPUC Energy Division and DNV for presenting the opportunity for public review and comment of the Draft Impact Evaluation of Residential HVAC Measures – Program Year PY2020. We feel that the steps in the reporting process should include at least one more opportunity for comments after the draft comments are submitted and before the final report is published which would increase the quality of the final report.	Thank you. We appreciate the review and stakeholder feedback. The standard process is to present evaluation results based on the draft report to stakeholders and then update the report, as needed, based on edits/comments to address stakeholder feedback.
46	GreenFan	54	DNV Section 6 Impact Results Page 54: “Fan controls continue to be present in the measure mix for this program year and there was some concern that their savings mechanism overlaps with one of the savings capabilities of the smart thermostats.” **Comment #1 - Smart Communicating Thermostat Cooling Delays.** DNV indicates a misunderstanding that the fan control “savings mechanism overlaps with one of the savings capabilities” of Smart Communicating Thermostats (SCT). Smart thermostats do not provide a similar feature to fan controls. Fan Controls (FC) provide variable fan-off delays from 2 to 6 minutes based on the duration of the AC cycle. The Efficient Fan Controller (EFC) also provides variable fan-off delays of 2 to 5 minutes after heating cycles. Ecobee has a default fixed 30 second delay for both heating and cooling. Most new HVAC systems include a fixed built-in delay of 30, 60, or 90 seconds. The Ecobee default 30-second delay will not provide any energy savings above the built-in HVAC delay. The Nest thermostat has a function called Airwave. Airwave includes Early Air-conditioning Compressor Turn-off (EACT) which reduces cooling capacity and cooling efficiency causing comfort issues and more frequent less-efficient Air Conditioning (AC) cycles. Airwave is not a default, and contractors are not given instructions to enable Airwave. If Airwave is enabled, the delays from field tests are short and in most cases less than 1-minute. As stated above, the EFC provides 2-to-6-minute variable fan-off delays after AC cycles and 2-to-5-minute variable fan-off delays after heating cycles. Longer variable cooling fan-off delays remove water from the evaporator coil for biofilm prevention to maintain proper airflow and indoor air quality (IAQ).1 Footnote 1: Free-floating pathogens such as viruses, bacteria, mold, fungi, mites, and dust attach to water on evaporator coils and produce a slimy biofilm colonizing the surface in a complex 3-dimensional structure within hours to reduce airflow. Biofilms propagate and cells eventually detach from the coil surface and flow downstream into the conditioned space reducing indoor air quality. Center for Biofilm Engineering. University of Montana. https://biofilm.montana.edu/.	DNV based its reporting of the add-on fan control delay function on the statewide workpaper. The statewide workpaper says that there two types of add-on fan controllers - one with built-in logic to delay the evaporator fan cycle-off time, but does not say by how much, and another with a manual evaporator fan controller that extends evaporator fan operation for 0 to 90 seconds. However, we will edit the report to clarify the functional differences between built-in or add-on fixed and variable fan delay and SCT functionality as stated in response to comments #38 and #40.

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47	GreenFan	7, 22	DNV Executive Summary - 1.4 Key findings 1.4.1 - Gross and net impacts Table 1-1, Page 7 provides no fan control heating savings and DNV Section 3 Methodology 3.1.3 Energy Consumption Footnote 27 (p. 22): states "... There were no gas savings claims for fan controls. "Comment #2: There are 3600 Efficient Fan Controller (EFC) units installed in four mobile home programs that provided a variable fan-off delay for heating and cooling. Please consider assigning some therm savings to the efficient fan controller (EFC) based on Intertek tests showing 13% EFC gas savings compared to Intertek tests showing 28% DTS gas savings. 2 The EFC provides 2-to-5-minute variable fan-off delays after heating cycles. The fan-off delays for heating cycles deliver more heat to the conditioned space causing longer off-cycles between thermostat calls for heat. Therefore, please assign some therms savings to the EFC measure.	All evaluated fan control measure savings claims were made under statewide workpaper SWHC029-01. This workpaper supported no heating savings in its methodology and the measures under this workpaper afforded no claimable therm savings. If there were fan control measure claims outside of programs we looked at, they were not identified in tracking data used in the study. The statewide workpaper SWHC029 is scheduled to be updated as DEER transitions to the EnergyPlus platform and the heating system savings capability of logic-based controllers can be included as part of the measure savings update.
48	GreenFan	12, 13	DNV Section 1.6 Recommendations - 1.6 pages 12-13 and Section 7 Conclusions and Recommendations, pages 58-59 Comment #3 – Fan control measures increase energy savings. Please consider adding the following recommendation: "Fan controls with extended variable fan-off delays for cooling and heating have the potential to increase energy savings when installed as a stand-alone measure or when installed with a smart thermostat measure and provide no overlap. Specifically, Fan controls with longer variable fan-off delays for heating provide an opportunity for increasing heating energy savings."	While "fan controls with extended variable fan-off delays have the potential to save energy," the consumption data analysis from PY2019 indicated the combined savings of smart thermostats and fan controls to be lower when they are installed together than the sum of the individual measure savings when they are installed alone. There were not enough isolated fan control installations in PY2020 to investigate this issue further. Moreover, there were no claimed gas savings for fan controls as no available workpaper supported gas impacts in PY2020. Thus, our evaluation results do not support the suggested recommendation.