






Impact Evaluation of Water Heating Measures -

Residential Sector - Program Year 2019

EM&V Group A

CALIFORNIA PUBLIC UTILITIES COMMISSION

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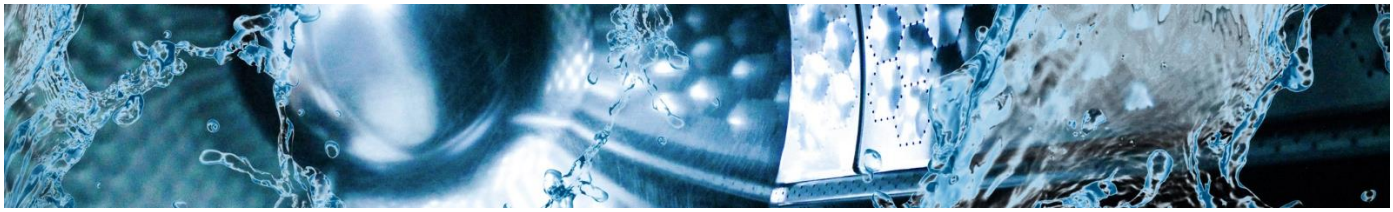

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1 EXECUTIVE SUMMARY

1.1 Background

Water heaters, sometimes referred to as the "forgotten appliance," account for a significant portion of a household's energy consumption. In California, water heaters account for roughly 25% of all household energy use, making them the second-largest single source of residential energy consumption after space heating.

Five California program administrators[1] (PAs) offered water heaters through plug-load/appliance, multifamily, and general residential energy efficiency programs in program year 2019 (PY2019). These programs delivered central natural gas storage water heaters (referred to as storage water heaters hereafter) and tankless water heaters (referred to as tankless water heaters hereafter), individual natural gas storage water heaters and tankless water heaters, heat pump water heaters (HPWHs), and boiler controllers[2] largely using rebate as well as direct install[3] channels. The programs targeted single-family homes, multifamily apartments, and mobile homes.

1.1.1 Research objectives

The research objectives of the water-heater evaluation are to:

- Estimate the level of savings that can be attributed to the program.
- Estimate energy savings (kWh and therm) per household and calculate realization rates.[4]
- Gather customer information on dwelling and household characteristics that inform unit energy savings such as dwelling type, square footage, household size, and hot water use behavior.
- Explore general awareness of PA rebates for water heating technologies, familiarity with and willingness to adopt emerging technologies such as HPWHs, willingness to participate in demand response programs, water use behavior, and demographics.

1.1.2 Study approach

PA programs provided incentives for water heater technologies to approximately 8,000 occupants and 1,000 multifamily properties. The evaluation team surveyed 1,052 occupants and 102 property managers of these PA water heater program participants and 1,376 non-participants drawn from the general population of residential customers that did not receive a rebate. The sample size for these surveys satisfies overall confidence and precision requirements of 90% +/- 10%. The evaluation employed web surveys to reach occupants and non-participants and phone surveys to reach property managers.

Table 1-1 below summarizes the key topics covered by the various research efforts as part of this evaluation. The participant survey informs estimates of the program's influence on the installation of water heater technologies. The survey also gathers additional information that provides context to hot water use behavior in the household. The non-participant survey allows us to compare the water heater technologies installed, hot water use behavior,

[1] Marin Clean Energy (MEC), Pacific Gas & Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), and San Diego Gas & Electric Company (SDG&E).

[2] Boiler controllers ensure that the boiler always maintains the set temperature of the water supplying the heating system. Boilers heat water and provide either hot water or steam for heating.

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

[4] Realization rate is the ratio of actual to claimed energy savings, A 100% realization rate means that, on average, savings were delivered as claimed/expected.

willingness to adopt water heater electrification technologies, and participation in demand response programs, of those not receiving a PA rebate.

Table 1-1. Summary of survey topics

Survey topic	Participants	Non-participants	Property Managers
Program influence on installation decision	•		•
Motivations for installation decision	•	•	•
Type of equipment replaced	•	•	•
Heat pump water heaters: Technology awareness and willingness to participate in demand response programs	•	•	
Dwelling characteristics: Building type, building vintage, and number of bathrooms	•	•	•
Hot water use: Showers, clothes washer loads, dishwasher loads	•	•	
Demographics: Household size, education, and income	•	•	

Table 1-2 below presents the sample size that informs the evaluation of the program's influence on the various water heater technologies.

Table 1-2. Sample size by water heater technology

Water Heater Technologies	Dwelling type	Sample size
Heat Pump Water Heater	Single-family	76
Natural Gas Storage Water Heater	Mixed	199
Natural Gas Tankless Water Heater	Mixed	762
Water heater technologies directed solely to multifamily		
Central System Natural Gas Storage Water Heater	Multifamily	4
Central System Tankless Water Heater	Multifamily	2
Recirculation Pump	Multifamily	53
Water Heater Boiler Controls	Multifamily	48

1.2 Key findings and recommendations

The key findings from the evaluation and the recommendations stemming from it are summarized in this section.

Program influence is lower than expected for single family. Occupant end-users, who largely reside in single-family homes, purchased HPWHs, storage water heaters, and tankless water heaters.[5] The study found the majority of savings (60% of storage, 64% of tankless, and 52% of HPWHs) would have occurred without program incentives. The timing of purchases is strongly affected by water heater failure or malfunction (63%) rather than program incentives (50%). Quantity is not a factor for this customer segment since single-family homes commonly have one water heater. Most customers state that they would have acquired the more efficient

[5] There was a small number of multifamily end-users who purchased HPWHs, storage, and tankless water heaters. However, there were too few to cause substantial changes to the NTGRs found for the single-family end users for those measures.

model even without the program. These findings lead directly to low program attribution with net-to-gross ratios (NTGRs)[6] of 40% for storage, 36% for tankless, and 48% for HPWHs.

We recommend that NTGRs from the evaluation be applied to PY2019 claimed savings for HPWHs, storage, and tankless water heaters.

Program influence is high for multifamily. Multifamily end-users purchased central systems, recirculation motors,[7] and boiler controllers. The NTGRs for the water heater technologies for multifamily were almost uniformly 100%. There are primary structural differences in the multifamily market compared to single family. Multifamily central equipment can be repaired almost indefinitely to maintain operations, while repairs for single-family water heaters are short-term fixes that eventually need replacement. Program incentives thus spur multifamily program participants to implement upgrades that they would have otherwise delayed or never undertaken as their existing equipment can be maintained and stay functional without requiring a replacement.

We recommend that NTGRs from the evaluation be applied to PY2019 claimed savings for recirculation pump controls and boiler controllers.

Given the low sample size for multifamily central system storage and tankless water heaters, we recommend no adjustments be made to NTGRs for PY2019 claims.

Rebates have a modest impact on motivation to install water heating technologies for single-family programs. PA program rebates in PY2019 ranged from $100 for storage to $300—$500 for HPWHs and $400—$600 for tankless systems. Evidence from NTGRs, coupled with program participants and non-participants stated motivation for installing equipment, point to a modest impact of rebates. There are several factors at play. First, a water heater is an essential piece of household equipment—people are not willing to go without a functioning water heater for a long time. Over half of the program participants (55%) indicated that equipment failure motivated their decision to replace their water heater. Over half of the non-participants (53%) stated equipment failure or end of useful life would motivate their future water heater purchase. Furthermore, only 9% of non-participants stated that their current water heaters had replaced working water heaters, while the remaining 91% of non-participant respondents replaced a broken water heater or one that was functioning but close to failure. While other factors such as environmental benefits and energy savings also motivate water heater replacement, the **timing** of purchases is strongly affected by equipment failure.

Secondly, **quantity** or water heater size is not likely to be strongly affected by the program because installers choose the correct system size that meets occupants' needs. This leaves **efficiency** level as the primary dimension that the program can affect. Our analysis of program influence reveals that the majority of those who switched (58%) indicated they would have installed the same efficiency tankless system without the program rebates. In other words, they were likely to purchase tankless systems anyway despite the substantially greater installation cost for tankless systems (especially when switching from storage to tankless).

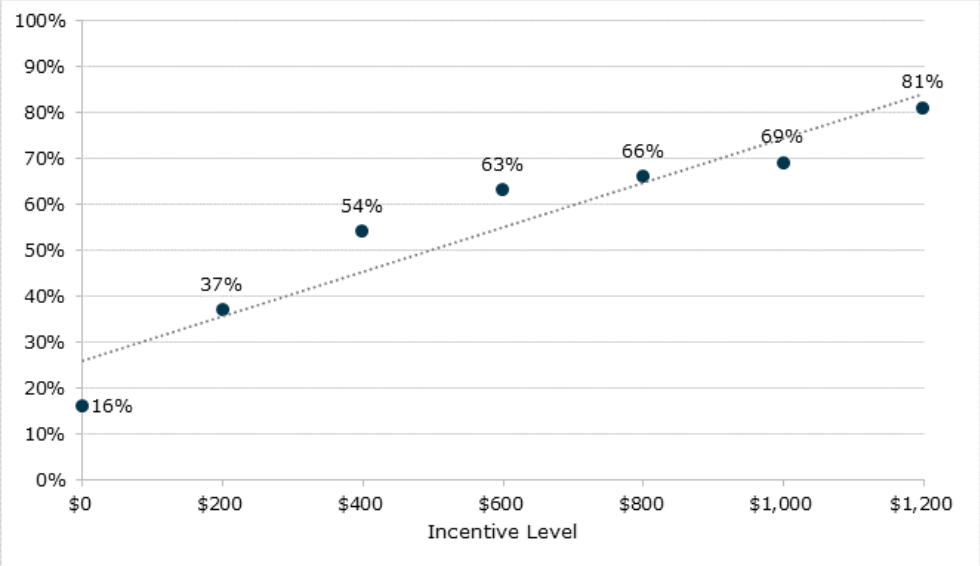
Moreover, program rebates (50%) and bill savings (46%) rated higher than environmental values (30%) on participants' reasons for purchasing a high-efficiency unit, underscoring that money matters. Results from the non-participant surveys support that higher rebates/incentives are more likely to motivate end-users to purchase and install high-efficiency water heaters. One-sixth (16%) of all non-participants indicated that they would

[6] The NTGR is the complement of free-ridership and measures the amount of savings attributed to program incentives. 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 lower value translating to greater program influence on a customer's decision to install the device and thus is more desirable. For example, an 80% NTGR indicates 20% free-ridership, meaning the program had greater influence.

[7] A hot water recirculation system is a plumbing system that moves hot water to fixtures quickly without waiting for the water to get hot. Rather than relying on low water pressure, common in most water lines, recirculating systems rapidly move water from a water heater to the fixtures.

consider a high-efficiency water heater with a price of $3,000 but cost $330 less to run per year compared to a standard efficiency conventional storage tank water heater that cost $1,000 (Figure 1-1). We randomly assigned non-participants to one of six groups and asked each group if they would consider purchasing the high efficiency model with a specific rebate amount: either $200, $400, $600, $800, $1,000, or $1,200. Only 16% of non-participants said they would purchase the high efficiency model with no incentive. Over four-fifths (81%) said they would purchase the high efficiency model with a $1,200 incentive compared to 54% that would do so if given a $400 rebate.

Figure 1-1. Non-participants' consideration of installing high-efficiency water heater by rebate level



Results indicate that increasing incentives could encourage mass market adoption of high efficiency water heaters in single-family homes. Programs should consider sliding scale incentives based on income eligibility to ensure that program influence is high and free-ridership is minimized.

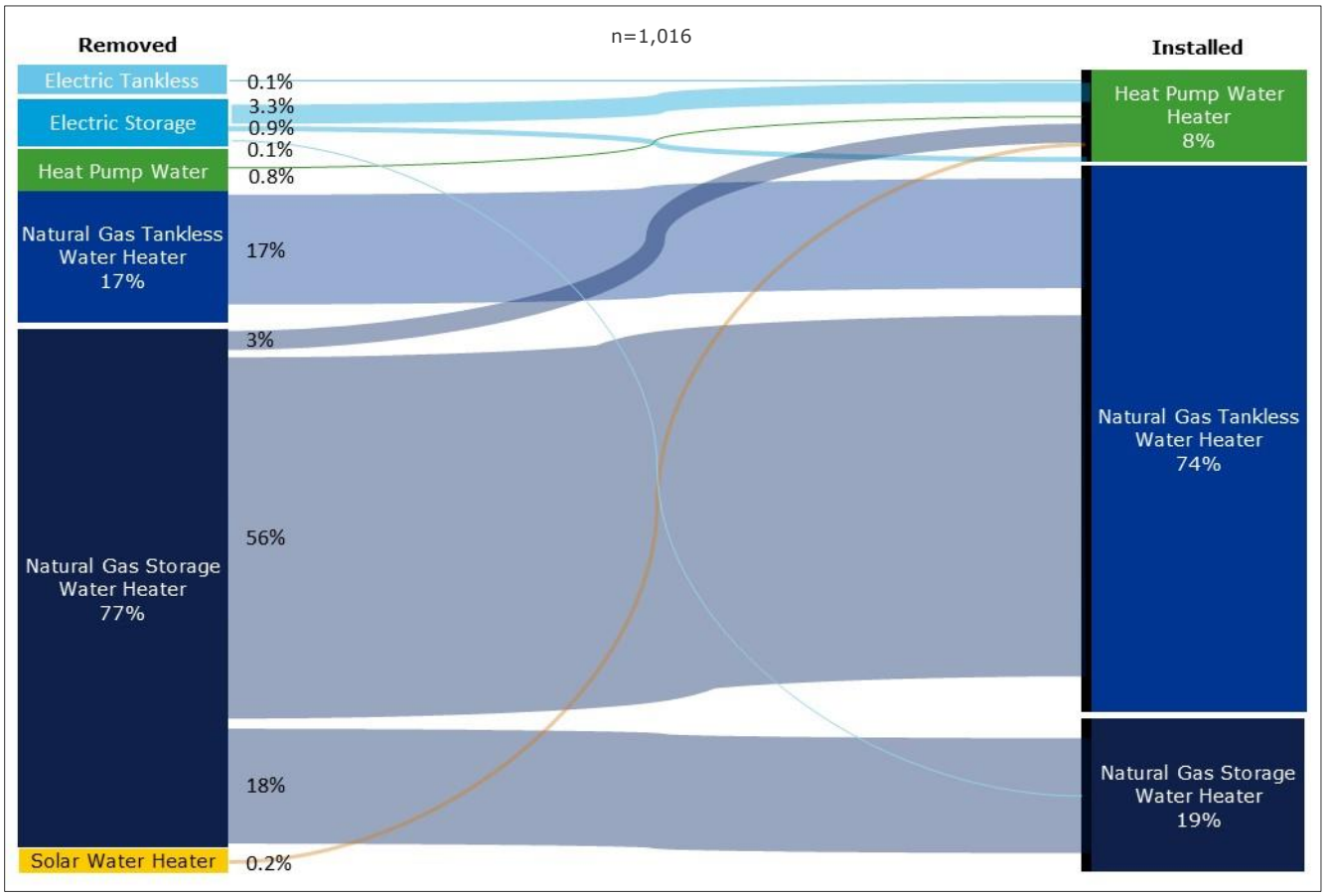
The program appears to be a critical factor for central systems installations among multifamily participants. Program influence on the installations was close to 100% (NTGRs of almost 1.0) for the central system water heater technologies installed by multifamily participants. Property managers indicated that they would have kept the equipment in service and repaired these as needed. Program incentives encouraged property managers to undertake higher-efficiency upgrades sooner and in greater quantity than they might have in the absence of the incentives. Furthermore, nearly four-fifths (79%) of property managers stated that the utility rebate motivated them to undertake the upgrades.

The single-family market is moving towards tankless systems, but fuel substitution is uncommon. The majority of participants (56%) indicated they switched from a natural gas storage water heater to a natural gas tankless, and all of the participants with tankless systems replaced in-kind. However, only 3% of participants switched from gas systems to electric systems in PY2019 (Figure 1-2). These program-incentivized conversions of gas to electric occurred prior to the changes to the fuel substitution test in CPUC Decision 19-08-009. Therefore, we would expect the next program year (PY2020) to have an increased share of gas-to-electric water conversions and even more so in PY2021 (based on new fuel substitution workpapers). Gross savings[8] for water

[8] Gross savings are defined as the change in energy consumption and/or demand by participants in an efficiency program, regardless of the program's influence on their decision to install an efficient technology.

heater technologies are dependent on the technology being replaced (baseline technology) and whether there is a change in fuel source for the same. The observed baseline is not necessarily consistent with what is assumed in the workpapers.

Figure 1-2. Program participants' (occupants) water heater replacement patterns



We recommend a gross impact evaluation that factors in the mix of baseline technologies for each program technology.

Future research using customer surveys is recommended to monitor the fuel-conversion trend from gas to electric heat pump water heaters in PY2020 and PY2021 pursuant to Decision 19-08-009.

Notably, tankless water heaters have a 20-year expected useful life versus the 11 years for storage water heaters. If participants continue to install tankless water heaters and remove storage water heaters, the average effective useful life of water heaters in California will increase. As a result, opportunities for fuel substitution may be delayed as there will be fewer equipment failures annually.

Going forward, programs must consider the increased measure life of tankless gas water heaters that will reduce and delay the opportunities for fuel substitution initiated due to equipment failure.

It may be necessary to consider replacing recent tankless gas installations before they reach the end of their effective useful life, given that these systems are expected to last until 2040 and this is by when the state aims to be carbon neutral.

There is work to do to overcome barriers to water heating electrification. The majority (91%) of non-participants' water heaters were fueled by gas. Given the importance of heat pump water heaters to achieving climate benefits through electrification, PAs need to do more to help customers overcome barriers:

- **Awareness.** Approximately half the participants who installed heat pumps were unaware of the technology prior to starting their project (48%). Nearly three-fourths (72%) of non-participants were unaware of heat pump water heaters, with 48% citing unfamiliarity with the technology as the primary reason for not wanting to install heat pump water heaters.
- **Upfront costs.** Nearly two-thirds (65%) indicated they had additional expenses on some combination of wiring, plumbing, and electrical panel upgrades. Nearly one-fifth (19%) of heat pump adopters indicated that they had to undertake an electrical panel upgrade. Among non-participants, the most frequently mentioned barrier to electrification was operating cost (47%), followed by existing equipment still being in good condition (34%), purchase price (33%), and panel upgrade requirements (29%).

The cost to replace an electrical panel averages $1,138, with a typical range of $498—$1,781.[9]

To overcome barriers to electrification, programs should focus on educating customers on efficient electric water-heater technologies and their operating costs.

Programs should address often-hidden costs such as panel upgrades with additional education and incentives to customers and the contractors that serve them.

Demand response potential is significant. Given the peak load reduction potential of water-heater demand response programs, we asked respondents to indicate their willingness to participate in such programs. While approximately one-third (36%) indicate disinterest, promisingly over one-half (54%) of program participants indicate some level of interest in participating in water heater demand response programs and represent potential peak load-shifting opportunity for utilities. Similarly, nearly two-thirds (64%) of non-participants indicated some level of interest in participating in a water-heater demand response program.

We recommend PAs encourage enrollment in water-heater demand response programs of customers that avail of program incentives to purchase HPWHs to maximize the energy savings potential of HPWHs.

There are lost opportunities for water-heater program energy-efficiency savings. A minority of single-family and multifamily participants and non-participants report that their water heater pipes are insulated (28%, 12%, and 20%, respectively) and that their water heater equipment is installed in a conditioned space (17%, 3%, and 19%, respectively). Insulated hot water pipes reduce heat loss and can keep water temperature 2°F–4°F hotter than uninsulated pipes, allowing customers to lower their water temperature setting. Consequently, when customers do not have to wait as long for hot water when they turn on a faucet or showerhead, this also helps conserve water and reduce the energy intensity of water. While pipe insulation may not make economic sense as a stand-alone project, ensuring that pipe insulation is bundled with water heater installation and repairs will be worth the effort.

[9] https://www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/

We recommend that best practices such as pipe insulation be formalized as a program requirement.

This should be accompanied by education to contractors who provide installation services and customers who receive them to enable achieving deeper savings.

PAs should also consider field data collection to determine if installations are compliant with pipe insulation requirements that meet industry standard practice, and credit insulation activity separately from the program. Results from the study may be used to inform workpaper updates.

A majority of non-participants indicate they search on the web or go to PA websites for information on new water heaters. Non-participants said they would search the web (52%) and go to PA websites (41%) or ENERGYSTAR.gov (37%) for information on new water heaters. Four-fifths (80%) of non-participants' water heaters were conventional storage and one-quarter (25%) were near the end of their useful life, indicating substantial opportunity exists for energy savings from efficient water heaters. Nearly one-half (46%) of non-participants preferred an instant discount and an additional 41% said either an instant discount or mail-in rebate was fine. Reduction in energy bills (69%) was the top factor influencing non-participants' water heater purchase decisions. The most important factor in deciding to claim a rebate for energy efficient equipment (cited by 81% of non-participants) was that the equipment did not require any changes to the home.

Optimize PA websites to increase visibility of efficient water-heater technologies and available rebates in search engine results.

Programs should offer both instant and mail-in rebate options and ensure that these appear in ENERGYSTAR.gov's rebate finder.

Programs should also leverage contractors as a key channel to market efficient water heaters to customers given that 50% indicated that contractor recommendations are a key source of information when considering purchase of a new water heater. The contractor channel is especially important for the 20% of the market that indicated personal recommendations were their only source of information when considering purchase of a new water heater.

Emphasize the benefit of energy bill reduction of efficient water heater technologies in marketing messaging.

Over one-third (36%) of non-participants had participated in a PA sponsored energy-efficiency program in the past. Past behavior is often a good predictor of future behavior. The PAs can target specific demographics to achieve the "low hanging fruit" with respect to water heater energy savings. These customers may be more inclined to participate in an efficient water heater program due to their awareness of energy-efficiency programs and familiarity with the participation process. Awareness of and likelihood to consider energy-efficient water heater technologies increased with income and education, as did willingness to consider purchasing a high-efficiency water heater without a utility rebate. Past participation in energy-efficiency programs and interest in a water heater demand response program also increased with income and education.

Target customers who have participated in energy-efficiency programs in the past to boost water heater program engagement.

Factors influencing purchase vary by PA. PG&E and SCG customers were the most likely to consider carbon emissions in purchase decisions (40% and 39% respectively). SCG customers were the most likely to cite operating cost (61%) and purchase price (47%) as barriers to electrification, and rebates (75%) as factors influencing water heater purchase decisions.

PG&E and SCG should consider highlighting environmental benefits in marketing materials.

SCG should prominently feature rebates and operating cost benefits in marketing materials.

2 INTRODUCTION

2.1 Program description and participation

Five California PAs offered water heaters through plug-load/appliance, multifamily, and general residential energy-efficiency programs in program year 2019 (PY2019). Table 2-1 provides the list of programs and measures installed. PAs delivered central natural-gas storage and tankless water heaters, individual natural-gas storage and tankless water heaters, heat pumps, and water heater controllers through these programs largely using rebates, but also through direct install channels. The measures targeted single-family, multifamily, and mobile homes.

Table 2-1. PY2019 programs offering water heater measures

PA	Program Name	Target	Delivery Method	Measures Offered
MCE	Multifamily	Multifamily	Downstream rebate	Central Natural Gas Tankless Water Heater (95% UEF) Recirculation Pump Demand Controls
PG&E	Enhance Time Delay Relay	Multifamily	Direct Install	Recirculation Pump Demand Controls
	Residential Energy Efficiency	Multifamily	Downstream rebate	Heat Pump Water Heater
	Residential Energy Efficiency	Single Family	Downstream rebate	Heat Pump Water Heater
	Residential Energy Fitness program	Single Family	Direct install	Heat Pump Water Heater
SCE	Plug Load and Appliances Program	Single Family	Downstream rebate	Heat Pump Water Heater
SCG	RES-On Demand Efficiency	Multifamily	Direct install	Recirculation Pump Demand Controls
	RES-Plug Load and Appliances - POS	Single Family	Midstream rebate	Natural Gas Tankless Water Heater
	RES-Residential Energy Efficiency Program	Mobile Home	Downstream rebate	Natural Gas Tankless Water Heater
	RES-Residential Energy Efficiency Program	Multifamily	Downstream rebate	Central Natural Gas Tankless Water Heater Natural Gas Tankless Water Heater Natural Gas Storage Water Heater W/H-Boiler Controllers
	RES-Residential Energy Efficiency Program	Single Family	Downstream rebate	Natural Gas Tankless Water Heater Natural Gas Storage Water Heater
SDG&E	SW-CALS-Plug Load and Appliances-HEER	Single Family	Downstream rebate	Heat Pump Water Heater Natural Gas Storage Water Heater Natural Gas Storage Water Heater
	SW-CALS-Plug Load and Appliances-POS Rebates	Mobile Home	Downstream rebate	Heat Pump Water Heater Natural Gas Storage Water Heater
	SW-CALS-Plug Load and Appliances-POS Rebates	Multifamily	Downstream rebate	Heat Pump Water Heater
	SW-CALS-Plug Load and Appliances-POS Rebates	Single Family	Downstream rebate	Natural Gas Storage Water Heater

Source: PA tracking data filed with the CPUC

Statewide, PA programs were responsible for the installation of over 8,000 gas saving and more than 800 electric saving water-heater measures in customer homes in PY2019. The PAs reported water-heater measure savings claims of approximately 1.5 million kWh and 1 million therms for 2019. Total installations covered a range of

measures, with the majority (over 60%) being small natural gas tankless water heaters accounting for about 30% of the claimed gas savings and largely installed among single-family homes. By contrast, water heater control measures (water heater boiler controllers and recirculation pumps) installed at multifamily buildings serving multiple dwelling units accounted for 11% of the installations but have gas savings claims of almost 60%. Table 2-2 provides details of the complete measure mix and with gas and electric savings claims by PA.

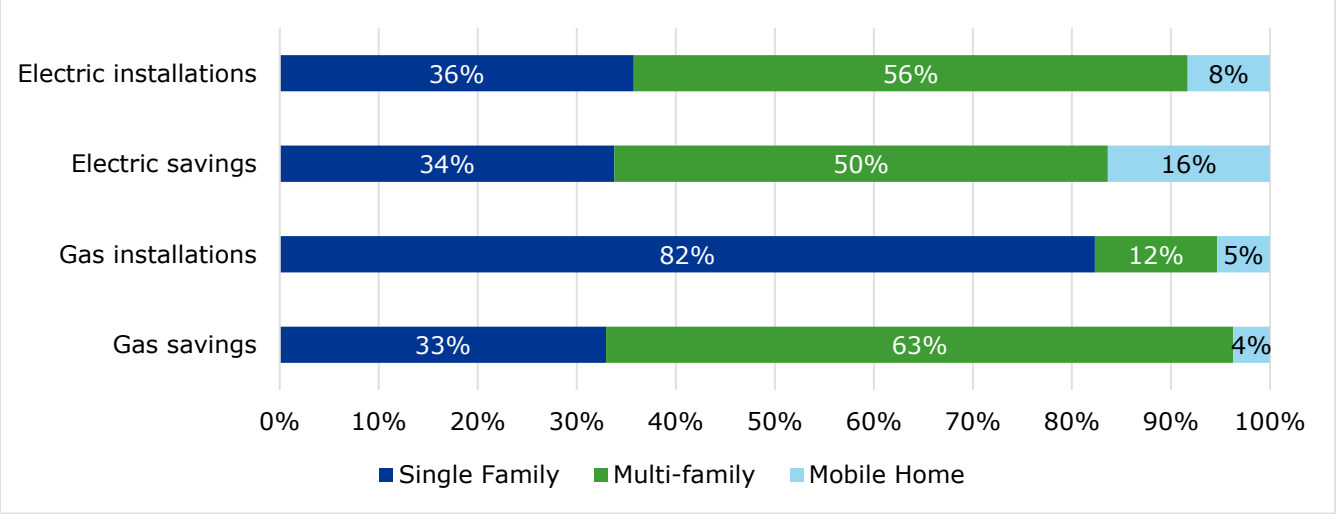
Table 2-2. PY2019 water heater measure installations and savings by PA

PA	Measure	Unit	Installations with Gas Savings Claims	Gross First Year Gas Savings (therms)	Gross Unit Gas Savings (therms)	Installations with Electric Savings Claims	Gross First Year Electric Savings (kWh)	Gross Unit Electric Savings (kWh)
MCE	Central System Tankless Water Heater	kBtuh	1	1,814	1.9			
	Water Heating Controls	Household	3	7,940	23.7	3	9,347	27.9
PG&E	Heat Pump Water Heater	Each				261	449,880	1704.1
	Water Heating Controls	Each	36	20,404	566.8	36	26,075	724.3
SCE	Heat Pump Water Heater	Each				15	24,982	1665.5
SCG	Central System Natural Gas Storage Water Heater	kBtuh	26	24,200	1.1			
	Central System Tankless Water Heater	kBtuh	11	26,189	3.1			
	Natural Gas Tankless Water Heater	Each	5,663	293,717	50.1		-17,701	-3.0
	Natural Gas Storage Water Heater	Each	1,392	42,175	25.4			
	Water Heating Controls	Household	899	558,929	16.1	422	686,520	38.8
SDG&E	Heat Pump Water Heater	Each				105	308,070	1488.3
	Natural Gas Storage Water Heater	Each	536	39,642	30.1			
Statewide			8,567	1,015,009	-	842	1,487,173	-

Source: PA tracking data filed with the CPUC

Figure 2-1 summarizes claimed electric and gas installations and savings by dwelling type.

Figure 2-1. Percent electric and gas PY2019 installations and claimed savings by building type

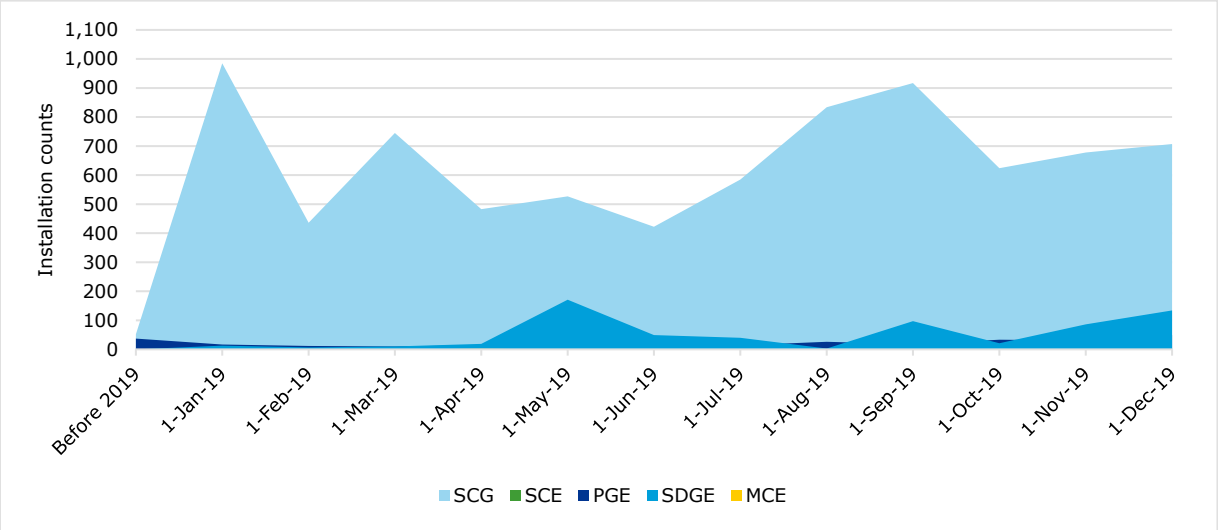


Areas where water heater measures were installed in program year 2019 are shown in Figure 2-2. As the figure indicates, the majority of water heaters were concentrated in the southern part of the state, particularly in zip codes served by SCG and, to a lesser extent, by SDG&E.

Figure 2-2. Geographic concentration of PY2019 installations

Figure 2-3 illustrates the timing of participation in these programs. There is no seasonal pattern to water heater installations, although a sizeable number were installed early in the year and late summer. There were also a handful that were installed prior to but claimed in 2019. The figure indicates the relative size of installations by PA, where it makes it apparent that most water heater installations were done by SCG.

Figure 2-3. Timing of 2019 installations



2.2 Evaluation objectives

The areas of parametric uncertainty identified in the PY2019 Efficiency Savings and Performance Incentive (ESPI) list for water heater measures include installation rate, realization rate, effective useful life (EUL), and unit energy savings (UES). The following are the evaluation objectives:

- Estimate the level of savings attributable to the program by estimating free-ridership.
- Estimate installation rates and net realization rates.
- Determine the differences in savings, if any, related to:
  - Baseline consumption.
  - Customer characteristics such as occupancy, water use behavior, and dwelling characteristics.
- Explore non-participant:
  - awareness of PA rebates for water heater measures.
  - familiarity with emerging technologies such as heat pumps and willingness to adopt.
  - willingness to participate in demand response programs, water use behavior, and demographics.

3 METHODOLOGY

This section details the approach DNV used to evaluate water heater measures.

3.1 Data sources

Table 3-1 summarizes the various sources of data used in the PY2019 evaluation.

Table 3-1. Data sources used for 2019 water heater measures evaluation

Data	Source	Period Covered	Contents
Program tracking data	California Energy Data and Reporting System (CEDARS)[10]	2019	Program information (program IDs, claimed savings, measure type, number of installations)
Customer Information Systems (CIS) data	PAs	2019	Participant and non-participant information (location, contact information)
Primary research data	Customer surveys	2019	Program attribution, hot water use behavior, customer characteristics

3.2 Savings estimation

In this study, DNV applied survey-based installation rates to the count of measures delivered per program tracking data to inform gross savings. If the study findings indicated that all installed units were still in service, we passed through ex ante savings. For a reasonableness check of the claimed savings values (unit energy savings or UES), electric (kWh) and gas (therm) per-unit tracking savings were compared to 2019 RASS water heating end-use UECs for single-family homes. We focused primarily on surveys to determine attribution and evaluate net energy savings that were claimed.

3.3 Survey approach

This section provides details on the primary research efforts undertaken as part of this evaluation. We surveyed participants (occupants and property managers) and non-participants.

3.3.1 Participants and non-participant surveys

The evaluation team administered participant surveys to customers who were the decision makers for water heater measure installations in their households and availed themselves of a program rebate for these installations. The objective of these surveys was to inform estimates of installation rates and free-ridership (and the complementary NTGRs or program attribution estimates) that were applied to derive net savings estimates. Surveys also gathered information on age of the replaced equipment, hot water use behavior, likelihood to participate in demand response, and demographics from both participants and non-participants.

The evaluation team also surveyed non-participant customers drawn from a random sample of utility customers sampled by consumption tiers and climate zone. The primary objective of the non-participant surveys was to provide a reference point related to demographics and hot water use behavior. The non-participant survey also served as a market characterization study that gathered information on gas equipment in the home, awareness of heat pump water heaters and willingness to electrify and participate in demand response programs.

[10] CEDARS provides information on all PA program installations and the amount of energy savings these installations are expected to generate https://cedars.sound-data.com/

3.3.2 Property manager surveys (participants)

Water heating controls and central gas water heaters were installed in multifamily dwellings through rebate and direct install channels. Property managers were the decision makers responsible for installation of these measures for customers residing in that property. The evaluation team surveyed property managers to inform installation rate and free-ridership estimates.

3.3.3 Survey topics

The complete surveys the evaluation team conducted are provided in Appendix G. Topics covered by the participant, non-participant, and property manager surveys are summarized below (Table 3-2).

Table 3-2. 2019 Survey topics – participants, non-participants, and property managers

Survey topic	Participants	Non-participants	Property Managers
Verify type and quantity of equipment installed	•		•
Motivations for installation decision	•	•	•
Type of equipment replaced	•	•	•
Heat pump water heaters: Technology awareness, anticipated associated cost of installation, willingness to participate in demand response programs	•	•	
Willingness to consider alternative water heater technologies and barriers to installation		•	
Purchase process: contractor influence and customer engagement in purchasing process	•	•	
Awareness of IOU programs		•	
Barriers and enablers of program participation		•	
Free-ridership questions (overall likelihood, timing, technology type, quantity, and efficiency)	•		•
Current water heater fuel source, water heater equipment type, and age of equipment		•	•
Emergency/early replacement	•	•	
Cost sensitivity		•	
Identify market segments most likely to participate in program in the future		•	
Dwelling characteristics: Home type, building vintage, square footage, number of bathrooms, household size	•	•	•
Hot water use: Showers, baths, clothes washer loads, dishwasher loads	•	•	
Installed equipment features: Temperature setpoint/range, pipe insulation, installation in conditioned space, faucet aerators, low flow showerheads, Energy Star equipment	•	•	•
Demographics: number of occupants, changes in occupancy, education, primary household language, race, and income	•	•	

3.4 Program attribution

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

We developed estimates of the ratio between the net and gross levels of savings (the net-to-gross ratio or NTGR). A ratio equal to 100% or 1.0 means the PA-sponsored program completely influenced water heater

installation and anything less than one indicates the level of free-ridership; for example, 25% free-ridership would yield an NTGR of 75%.

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

The timing and efficiency components of free-ridership apply to both the occupant and the property manager surveys. Quantity only applies to the property manager survey. The various PA-delivered programs that provided water heater measures to residential customers gave rebates for just one installation per household. Quantity free-ridership thus does not apply to occupant surveys. However, because property managers could install one water heater *per unit*, quantity free-ridership still applies to capture the number of efficient water heater units that the property manager would have installed absent the program.

Survey question responses on the timing, efficiency, and quantity of the installations were scored using an algorithm to arrive at free-ridership and program attribution estimates. The surveys also included a question about the overall likelihood of installation absent program incentives that serves to verify the estimated free-ridership. The details of the algorithm used to determine program attribution are summarized in Appendix E. This is a standard methodology that has evolved in CA over the past several years. Section 4.3.7 presents program attribution estimates for the water heater measures considered in this evaluation.

4 SURVEY RESULTS

This section provides findings from the surveys, including program attribution, installation rates, and hot water use related-behaviors.

4.1 Survey mode and sample disposition

Participant and non-participant occupant surveys. We administered web surveys among program participants and non-participants. Participant surveys were fielded from September through October 2020, while non-participant surveys spanned a longer period from October 2020 to January 2021. Property manager surveys were administered by telephone and by email in instances where there were multiple projects to discuss with a single respondent. The sample frame for participant surveys were customers who had received rebated or direct-install water heater measures in PY2019.

DNV attempted a census approach for the participant survey. Participants with available email contact (and telephone for property managers) and not on the PAs' do-not-contact list were part of the sample frame for the survey. Participants were offered a $100 lottery incentive to complete the survey. All eligible completes were entered into a random drawing for the $100 incentive.

The sample frame for the non-participant survey was a random subset drawn from the PAs' customer lists and excluded those who had availed of PA incentives for water heaters and those who were on the PAs' do-not-contact list. Non-participant survey invitees received a $10 incentive for their survey completion. At least two reminders were sent through the survey fielding period for both participants and non-participants.

The surveys included both CPUC and PA branding to boost customer response. They also included a link to a dedicated page on the CPUC website that allowed respondents to validate the sponsor and the legitimacy of the surveys. The sample disposition for the occupant surveys of participants and non-participants is summarized in Table 4-1.

Table 4-1. Sample disposition for participant and non-participant surveys

Occupant: participants	PG&E	SCE	SCG	SDG&E
Invites sent	155	13	4344	80
Not started	87	11	3367	58
Incomplete	6	-	78	-
Completed	62	2	899	22
Response rate	40%	15%	21%	28%
Occupant: non-participants	**PG&E**	**SCE**	**SCG**	**SDG&E**
Invites sent	36,120	6,374	3,375	8,183
Not started	30,820	5,435	2,507	6,180
Incomplete	268	61	42	84
Completed	925	157	79	215
Response rate	2%	2%	2%	2%

Property manager surveys. DNV administered property manager surveys for installations where property managers served as the primary point of contact. The sample frame for these surveys was all PY2019 properties that received rebated or no cost water heater measures and DNV attempted a census approach to survey property managers of the properties. Due to a record of poor response to web surveys among this group, the evaluation team employed telephone surveys to reach property managers. The team made calls over a four-week

period beginning in late December 2020 through mid-January 2021. Similar to the participant and non-participant surveys described above, DNV offered a $100 lottery style incentive for assistance in completing the survey. The sample disposition for the property manager surveys is summarized below (Table 4-2).

Table 4-2. Sample disposition for property manager surveys

Property Managers	SCG
Sample projects	682
Not started	561
Incompletes	18
Completed	114
Response rate	15%

4.2 Sample weights

DNV applied sample weights to balance participant (occupants and property managers) and non-participant survey samples to population proportions by climate zone category and consumption level. Separate measure-level sample weights were applied for the NTGR analysis to balance samples within each PA by measure type. Details of the weighting procedure may be found in Appendix F.

Participant survey sample weights. No trimming of weights was required with the minimum weight, maximum weight, and the ratio of the maximum to minimum sample weight at 0.6, 1.7, and 3.1, respectively.

Non-participant survey sample weights. No trimming of weights was required with the minimum weight, maximum weight, and the ratio of the maximum to minimum sample weight at 0.7, 1.4, and 2.2, respectively.

Property manager sample weights. No trimming of respondent-level property manager weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.2, 2.1, and 10.8, respectively. Minimum cell size to which weights were applied was 3.

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

4.3 Participant survey results

4.3.1 Demographic profile of participants and non-participants - Occupants

In addition to informing the proportion of savings attributable to the program, surveys also provide relevant information on customer characteristics related to energy consumption. DNV surveyed participants and non-participants (customers who did not receive program discounted or free water heater measures). Non-participants are a select subset chosen randomly from a stratified frame along climate region and household gas consumption. Table 4-3 below presents a survey-based demographic profile of the non-participants and participants. Shaded cells represent significant differences between participants and non-participants.[11] The profile below also includes general population characteristics for the state of California based on the American Community Survey.

Both participants and non-participant respondents to the PY2019 surveys have a higher proportion of residents who live in newer, larger, and single-family homes and are more educated and affluent compared to the general

[11] Differences reported are at the 90% confidence and 10% significance level. The shaded cell is the significantly higher value in the comparison between participants and non-participants.

population in California. Furthermore, a higher proportion of program participants live in single-family homes and are more affluent but live in older homes compared to non-participants. Non-participant households have higher proportions of children and seniors in the household compared to participants.

Table 4-3. Demographic profile of non-participant and participant survey respondents[12]

Demographic Characteristics	California - American Community Survey[13]	Non-Participants (n=1,375)	Participants (n=1,052)
Dwelling Type			
Single family	69%	92%	97%
Multifamily	25%	6%	3%
Mobile Home	6%	2%	0.1%
Dwelling Vintage			
Before 1980	65%	50%	58%
1980-1999	26%	29%	24%
2000 and after	15%	21%	16%
Dwelling Size			
Less than 1,000 square feet	28%	7%	4%
1,000 to 2,000 square feet	48%	55%	49%
Greater than 2,000 square feet	24%	36%	46%
Household composition			
Average number in household	2.9	2.8	3.0
% Age 5 and under	6%	14%	5%
% Age 65 and over	15%	39%	28%
Language			
% Non-English primary language	45%	8%	10%
Education			
Lower than Bachelor's	49%	29%	27%
Bachelor's	22%	36%	37%
Higher than Bachelor's	13%	33%	30%
Income			
Less than $50,000	32%	16%	11%
$50,000 - $100,000	28%	29%	26%
Greater than $100,000	41%	55%	64%

4.3.1.1 Demographic profile of participants - Multifamily property managers

The DNV team conducted primary research with 114 property managers (projects) to determine program influence on installation of measures such as recirculation pumps and boiler controls. The majority were multifamily properties (89%) that were market-rate (87%) with no rent restrictions.

[12] Base sizes vary by specific question due to Don't know/Prefer not to say/Missing responses.

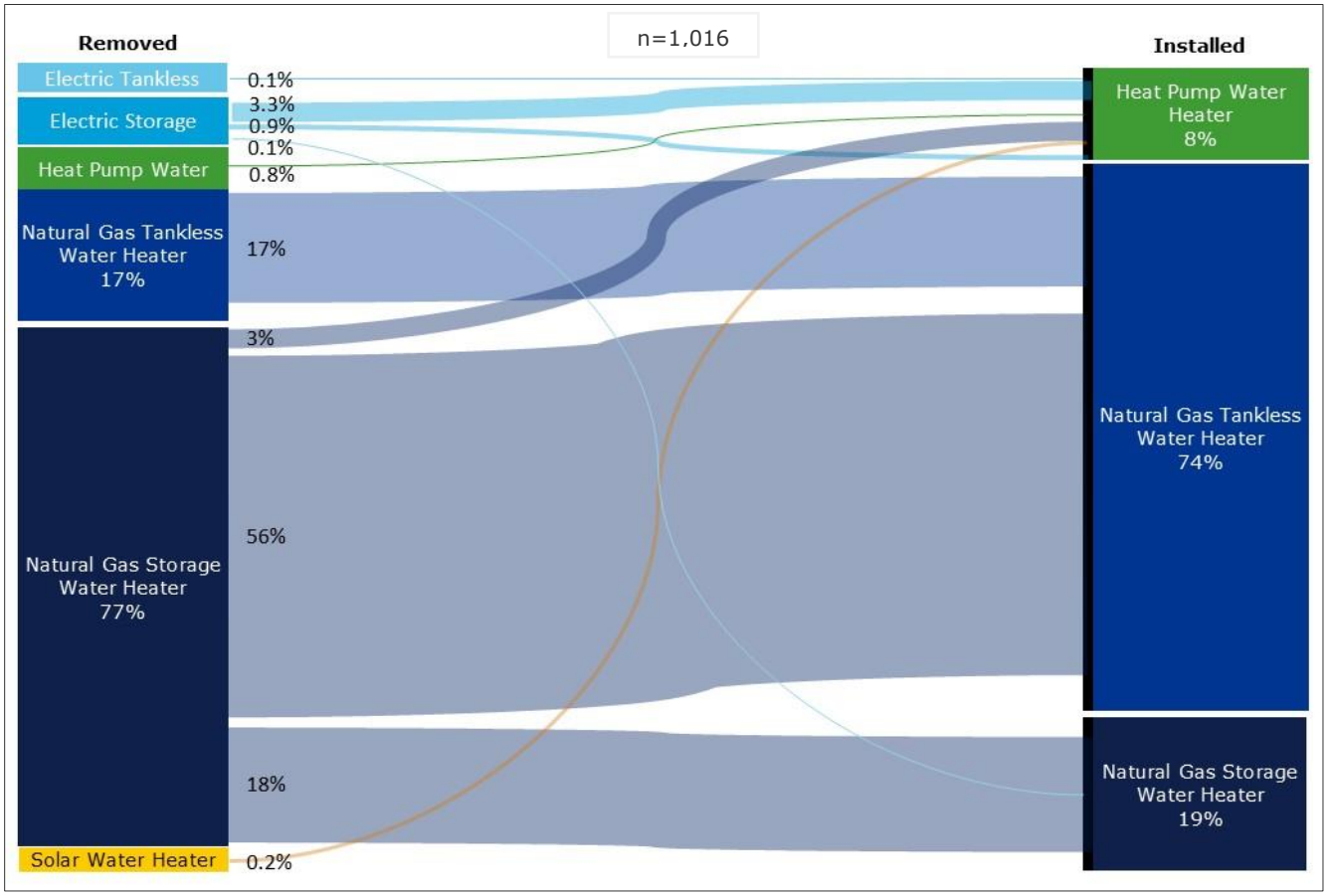
[13] California Profile, American Community Survey, https://data.census.gov/cedsci/profile?g=0400000US06

Unlike subsidized multifamily housing, market-rate properties have residents paying full market price and hence these properties are likely to have a lower proportion of low-income residents. The vintage of around two-thirds (65%) of these multifamily properties was pre-1980 and a smaller proportion of these properties were newer construction post-1980 (29%). As electrification of end uses including water heating increases, older buildings built prior to 1980 are likely to have panel size constraints and may require panel upgrades to support electrification.

4.3.2 Water heater replacement patterns

Occupants who were the decision makers for water heater replacements, mostly those residing in single-family homes, installed three main types of water heaters offered by PA programs: Natural gas storage water heaters, natural gas tankless water heaters, and heat pump water heaters. Figure 4-1 summarizes survey responses describing the types and magnitudes of the water heaters replaced under PA programs. The majority of natural gas storage water heaters (56%) were replaced by natural gas tankless water heaters. Survey respondents also indicated installing a notable proportion of heat pump water heaters through programs, which they used to replace mostly electric storage and tankless water heaters (4%).

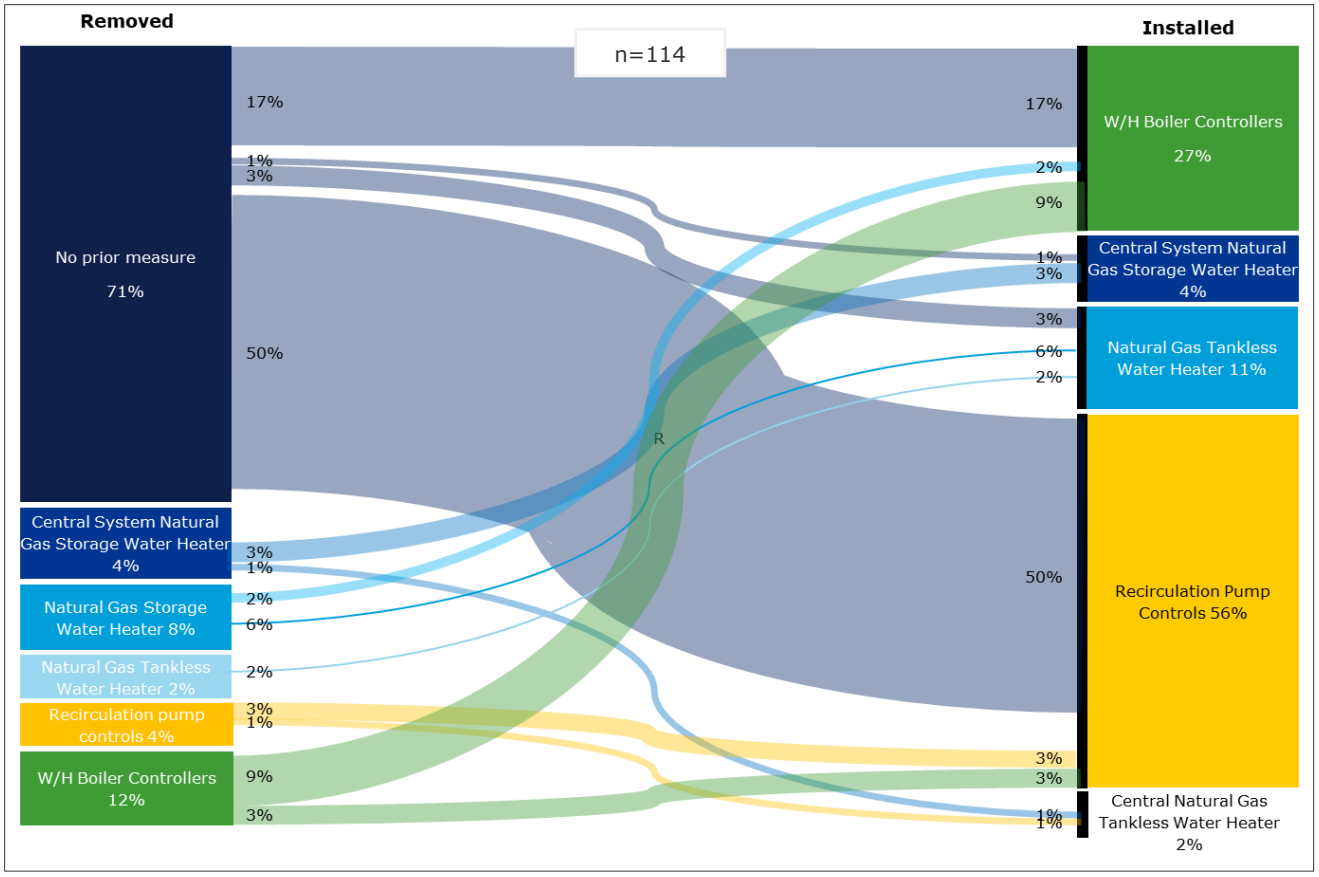
Figure 4-1. Water heater replacements for occupant decision-makers



The property manager surveys provide information on the technologies replaced and installed in multifamily properties by PA-incentivized water heater programs (Figure 4-2). Half of all property managers (50%) indicate that recirculation pumps were installed by the programs and 17% percent indicate receiving PA incentivized

boiler controllers. These were not replacements but new installations (where none existed previously) aimed to enhance the efficiency of the central water heater systems they control.

Figure 4-2. Water heater replacements for property manager decision-makers



4.3.3 Effective useful life

The tracking data indicate that the effective useful life (EUL) of program-offered natural gas storage water heaters is 11 years, that of natural gas tankless water heaters is 20 years, and heat pump water heaters is 10 years (Table 4-4). Central system natural gas water heaters (both storage and tankless), boiler controls, and recirculation pump controls installed in multifamily homes have EULs of 15-20 years, 6-7 years, and 15 years respectively.

Table 4-4. Age of replaced water heaters

Replaced Unit Type	Sample size	EUL per tracking data	Age of replaced unit		
			Less than 10 years	10-15 years	Older than 15 years
Heat Pump Water Heater	9	10 years	53%	39%	8%
Natural Gas Storage Water Heater	738	10 years	26%	40%	26%
Natural Gas Tankless Water Heater	171	20 years	36%	42%	17%

The age of the majority (66%) of natural gas storage water heaters that were replaced exceeded the EUL value of 10 years specified by the California Database for Energy Efficiency Resources (DEER), while the age of the

majority (> 78%) of natural gas tankless water heaters replaced was well below the DEER-specified EUL value of 20 years. The age of about half (53%) of heat pumps replaced was less than the DEER-specified EUL value of 10 years. The finding related to age of replaced heat pumps should be interpreted with caution given the low sample size.

4.3.4 Installation rate

Program tracking data indicate an installation rate of 100% for all measures. Survey responses indicate that except for one percent of the natural gas storage and tankless water heaters offered by SCG which were no longer installed due to malfunction, all other water heater measures were installed and still in place (Table 4-5).

Table 4-5. Installation rate by water heater measure

Measure	IOU	Percent installed water heaters
Heat Pump Water Heater	PG&E	100%
	SCE	100%
	SDG&E	100%
Natural Gas Tankless Water	SCG	99%
	SDG&E	100%
Natural Gas Storage Water Heater	SCG	99%

4.3.5 Motivations of water heater equipment installation - Occupants

While examining the age of replaced equipment reveals whether it may have been replaced early or due to burnout, the evaluation team asked participants to indicate their motivations for water heater replacement. The team also asked non-participants to indicate what would motivate them if they were in the market for water heaters. Figure 4-3 provides a combined picture of the motivations of water heater purchase among participants who availed of utility rebates and among non-participants who may participate in utility programs in the future.

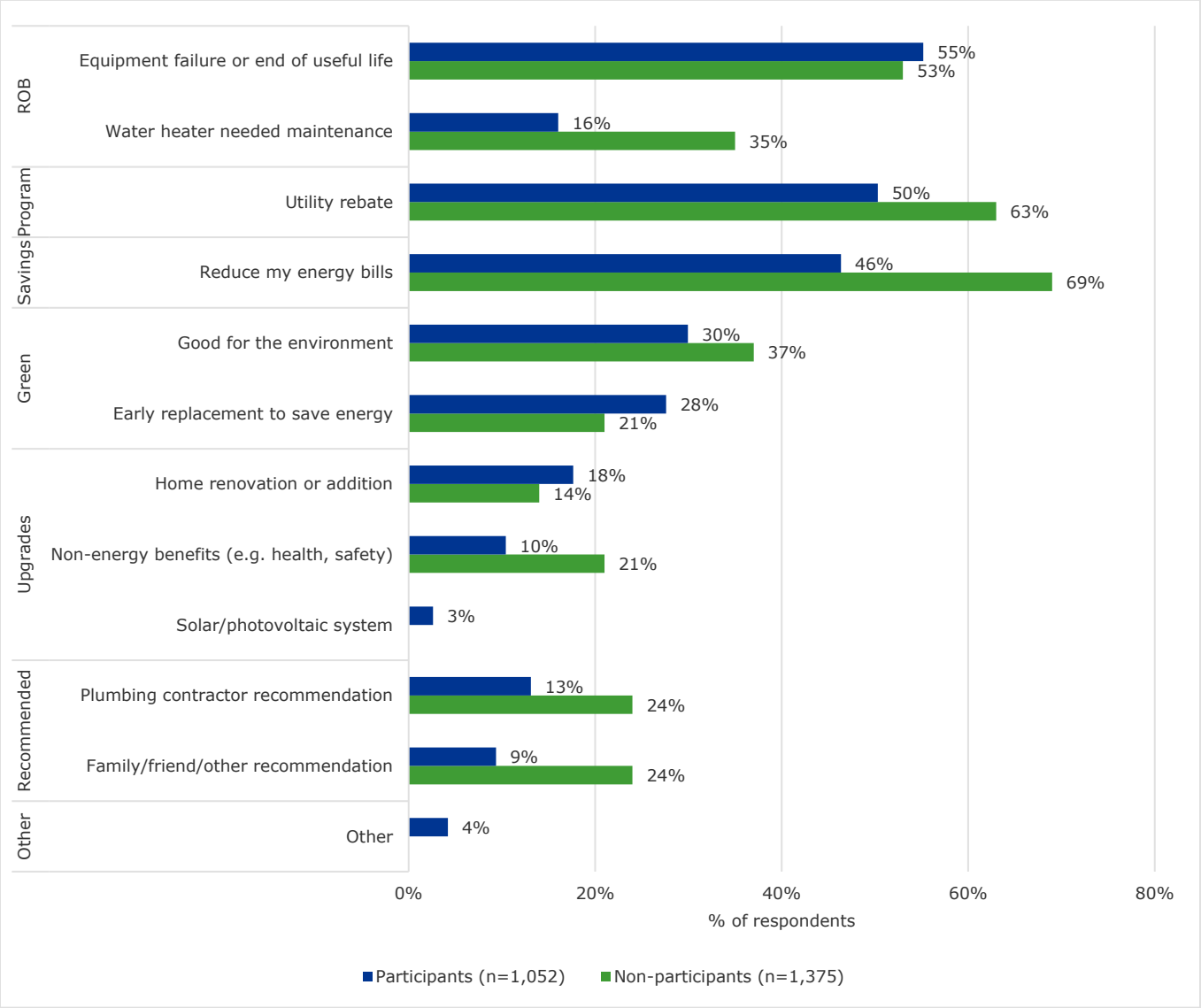
Equipment failure and increased maintenance needs rose to the top as motivations of equipment installation for participants. This corroborates the finding, presented in the previous section based on equipment age and EUL, that the majority of survey respondents, most of whom have natural gas storage water heaters, viewed water heating equipment as a "replace on burnout" or "normal replacement" measure.

Financial benefits from the upfront program rebate to purchase the water heaters and the ongoing bill savings realized from installation of efficient water heaters are the next most important motivations for participants and of highest importance to non-participants. It makes sense that financial benefits of an upgrade rise to the top for non-participants who are considering a prospective purchase without the immediate need of replacing a malfunctioning water heater.

A higher proportion of non-participants relative to participants indicate that they would be motivated to replace their water heater based on recommendations from friends and family (24% versus 9%) or their contractor (24% versus 13%). We recommend use of customer testimonials and strengthening trade ally networks to deliver PA programs that encourage adoption of energy efficient water heaters.

Customer desire to reduce carbon emissions and save energy round out the top five motivations for water heater upgrades for both participants and non-participants.

Figure 4-3. View of current (participant) and prospective (non-participant) motivation to replace water heaters

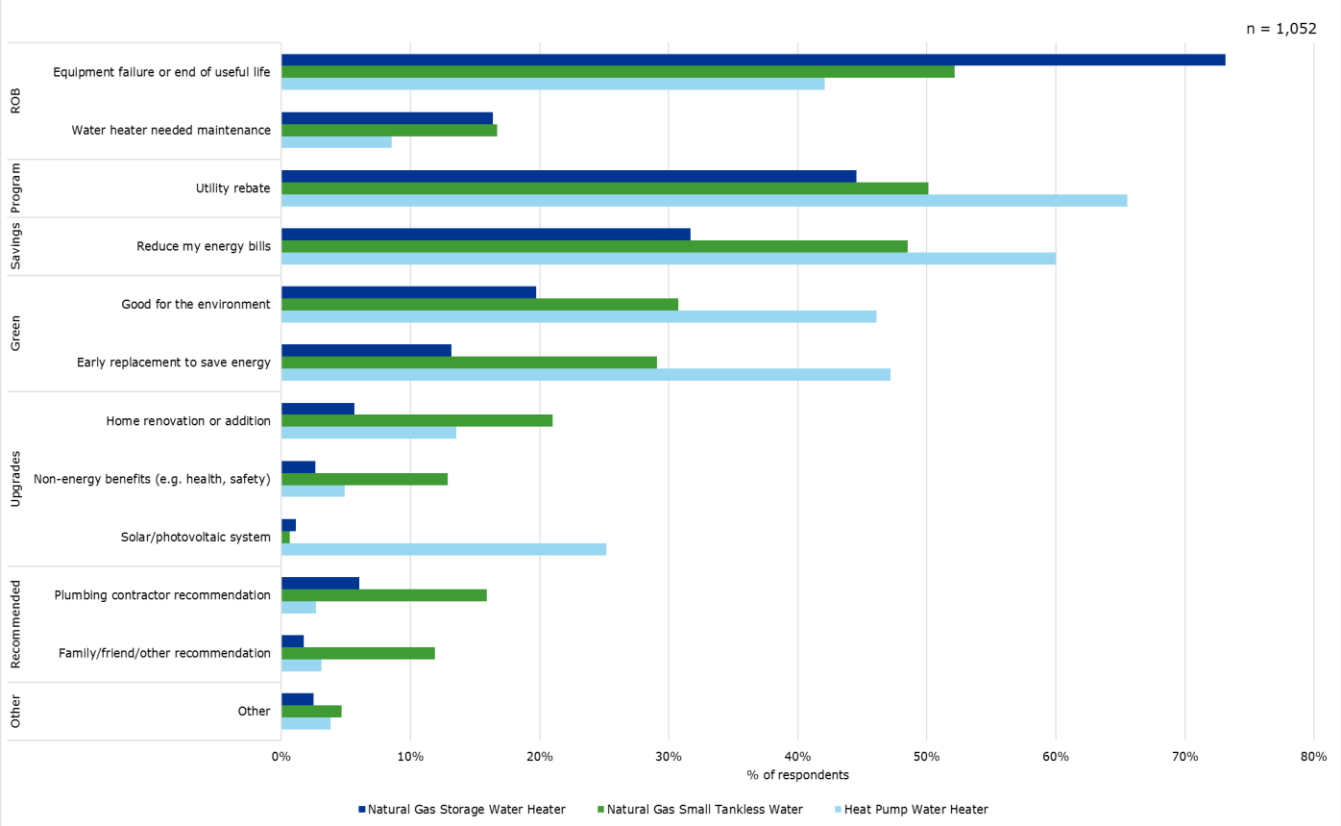


The motivations for water heater replacements by measure type are presented in Figure 4-4. Respondents indicate utility program contribution is a greater motivation for installing heat pump water heaters compared to motivation for replacing the older technology natural gas storage and tankless water heaters. This mirrors the lower program attribution found for the older technology water heaters compared to heat pump water heaters. That program support is an important motivation for heat pump water heater installations indicates that this emerging technology merits market transformation efforts.

Furthermore, survey respondents indicate the desire to reduce their energy consumption for environmental and budgetary reasons as their next most-important motivation for replacing their water heater with the newest heat pump water heater. Respondents who installed heat pump water heaters also indicated the presence of solar PV as a notable motivation for their water heater choice. This choice indicates synergies among certain technologies as building electrification ramps up. With the presence of solar, the adoption of electrical end uses become more

appealing; as more electrical appliances are added, the acquisition and use of solar becomes a more financially viable and attractive option.

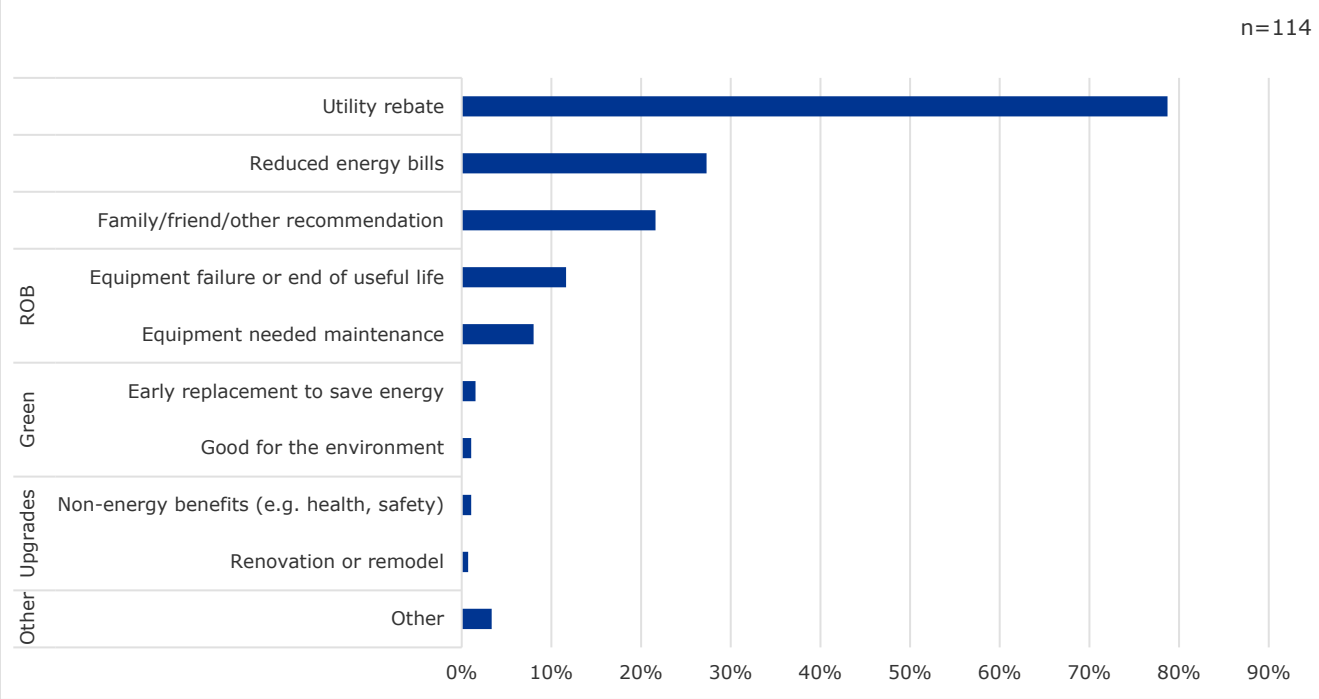
Figure 4-4. Occupant participant motivations to replace water heater, by measure



4.3.6 Motivations to replace water heater equipment - Property managers

While equipment failure is the leading motivation of measure installation among occupant participants, the majority of whom reside in single-family properties, utility program rebates are the most cited motivation by property managers at almost 80% (Figure 4-5). This indicates that multifamily properties considering planned upgrades are a desirable target for programs offering efficient water heating equipment.

Figure 4-5. Property manager decision-maker motivations of water heater replacement



4.3.7 Free-ridership and program attribution

The central objective of the participant surveys was to capture participants' self-reported responses that provide information on free-ridership and allow estimation of NTGRs that are used to calculate net savings estimates. This self-reported approach involved asking program participants a series of questions that were aimed at establishing if high-efficiency water heaters would have been installed in the absence of the program, and if so, the extent to which the installation might have differed in the absence of the program in terms of timing of the installation and efficiency of the water heater.

Occupants. Measures installed where occupants are decision-makers include natural gas storage and tankless water heaters, and heat pump water heaters. Program rebates for these measures varied by PA, but in general, they ranged from $100 to $175 for natural gas storage water heaters; from $400 to $600 for natural gas tankless water heaters; and from $300 to $500 for heat pump water heaters. In the case of programs with occupant decision-makers, participant surveys with occupants inform free-ridership.

Occupant surveys reveal lower program influence than claimed for single-family participants.[14] Heat pump, natural gas tankless, and natural gas storage water heaters were almost exclusively installed by respondents to the occupant survey. For each of these measures, attribution scores were under 50%, which indicates that the majority of savings (61% of storage, 64% of tankless, and 52% of HPWHs) would have occurred without program (Table 4-6).

Property managers. Property manager surveys inform free-ridership estimates in programs where the property manager is the decision-maker for multiple water heating measure installations rather than the occupants in the individual households receiving the measures. Water heater measures installed where property

[14] Most claims for all the measures installed (natural gas storage and tankless water heaters, water heater controls, and heat pump water heaters) apply NTGR values of 0.55, with a smaller subset of claims that use NTGR values of 0.70 and 0.85.

managers were the decision-makers include central storage and tankless water heaters, and water heater controls. Program rebates for these included $8 per mBtu for central system natural gas water heaters and $700 to $1,600 for water heater controls.

Property manager surveys reveal high levels of program attribution for this market segment. The central system measures, recirculation pumps, and boiler controls were installed only by respondents to the property manager interviews. For each of these measures, program attribution is near 100% (Table 4-6). This indicates that almost all of the savings that occurred from these measures are due to program influence.

Table 4-6. Program attribution (NTGR[15]) by measure

Measure	Decision-maker	n	kWh		Therms		kW		Influence Likelihood
			NTGR	Relative Precision	NTGR	Relative Precision	NTGR	Relative Precision	
Central System Natural Gas Storage Water Heater	Property manager	4			100.0%	0.0%			10.4%
Central System Tankless Water Heater	Property manager	2			100.0%	0.0%			57.6%
Heat Pump Water Heater	Occupant	76	48.1%	14.3%			47.1%	14.8%	67.6%
Natural Gas Storage Water Heater	Occupant	199			39.5%	12.7%			72.9%
Natural Gas Tankless Water Heater	Occupant	762	35.8%	6.9%	36.4%	6.9%	36.1%	7.0%	70.0%
Recirculation Pump	Property manager	53	100.0%	0.0%	100.0%	0.0%			14.2%
Water Heater Boiler Controls	Property manager	48			94.2%	7.6%			25.5%

Note: A significant majority of natural gas storage and tankless water heaters were in single-family residences where occupants are the decision makers.

The influence likelihood question included in the surveys as a consistency check confirmed the values of the free-ridership questions. The question asked participants if they would have purchased the same efficiency and type of water heater without the rebate. The pattern of responses for this question are consistent with the final scores derived from the timing, efficiency, and quantity free-ridership questions. For example, respondents that purchased a natural gas tankless water heater indicated that there was a 70% probability that they still would have bought the same natural gas tankless water heater without the rebate, which is consistent with the 36% NTGR. The influence likelihood is not used to calculate free-ridership or NTGR but is used as a confirmation check on the free-ridership score.

Table 4-7 shows attribution by measure for each PA. As shown in the table, the relative precisions range from 0% to 77.6% and do not support use of PA measure-specific NTGRs.

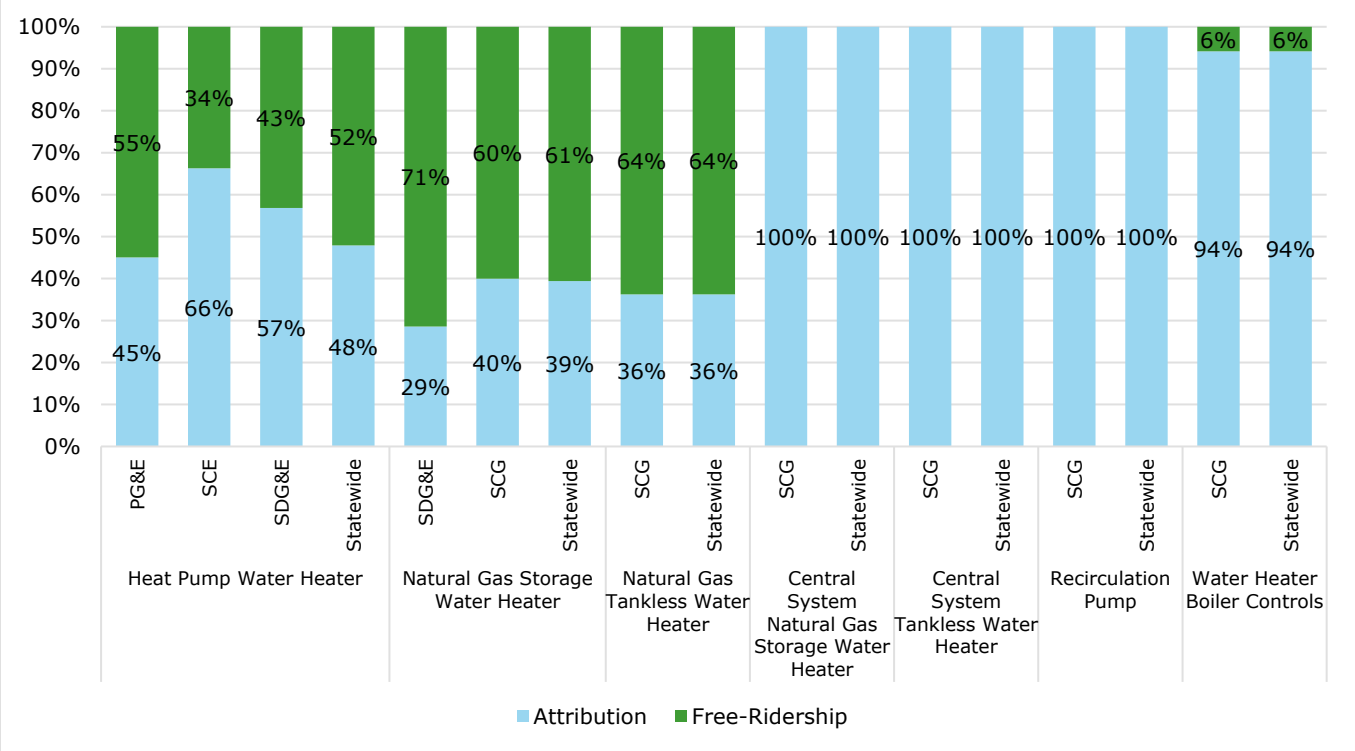
[15] The details of the free-ridership scoring algorithm used is provided in Appendix E. Participant and property manager survey based free-ridership estimates are weighted by PA gross savings claims to arrive at final program attribution estimates.

Table 4-7. Program attribution (NTGR) by PA measure

PA	Measure	n	kWh		Therms		kW	
			NTGR	Absolute Precision	NTGR	Absolute Precision	NTGR	Absolute Precision
PG&E	Heat Pump Water Heater	65	45.3%	14.8%			45.1%	14.8%
SCE	Heat Pump Water Heater	2	66.3%	76.1%			51.4%	77.6%
SDG&E	Heat Pump Water Heater	9	56.8%	37.4%			56.9%	37.5%
SDG&E	Natural Gas Storage Water Heater	13			28.6%	57.5%		
SCG	Natural Gas Storage Water Heater	186			40.1%	13.0%		
SCG	Natural Gas Tankless Water Heater	762	35.8%	6.9%	36.4%	6.9%	36.1%	7.0%
SCG	Central System Natural Gas Storage Water Heater	4			100.0%	0.0%		
SCG	Central System Tankless Water Heater	2			100.0%	0.0%		
SCG	Recirculation Pump	53	100.0%	0.0%	100.0%	0.0%		
SCG	Water Heater Boiler Controls	48			94.2%	7.6%		

Figure 4-6 shows program attribution and free-ridership by PA measure type and at the statewide level. PA NTGRs are weighted by gross savings claims to calculate statewide ratios. The lower free-ridership and hence higher program attribution for emerging technologies such as heat pumps versus older technologies such as natural gas storage and tankless water heaters is consistent with the adoption velocity boosting effect program incentives have on the market.

Figure 4-6. Program attribution (NTGR) and free-ridership



4.3.8 Gross and net savings

Installation rates and NTGRs (presented in section 4.3.7) are used to provide adjusted gross and net savings for programs that delivered the water heater measures covered in this report. Installation rates for the water heater measures covered in the report are very high given that end users are likely to obtain these measures for immediate use. On occasions when recipients have reported that these measures are no longer installed, the primary reason for their removal is malfunction. Since installation rates for water heater measure delivered by PY2019 programs are practically 100%, gross realization rates are 100% and claimed gross savings are not adjusted. Net savings reflect the estimated NTGRs of each equipment type. Details on gross and net savings by measure and PA can be found in Appendix A and Appendix B.[16]

4.3.9 Heat pumps

While typical heat pump water heaters can save 60% of annual water heating energy consumption compared to baseline, there has been little market penetration in the past 10 years. As discussed earlier in section 4.3.5, water heaters are typically replaced on burnout or due to malfunction. This leads to failure-based unplanned purchases to address a crisis and adoption of the most convenient option with little time to shop and learn about available efficient options and their energy savings potential.

Heat pump water heaters installed in single-family homes, where occupants are decision-makers, represent 5%[17] of all PY2019 water heater installations.[18] We discuss customer awareness of heat pumps, adoption costs, and willingness to participate in water heater demand response programs in the following sections.

4.3.9.1 Heat pump awareness

Limited consumer awareness and lack of an educated installer base that can present these choices to consumers have been identified as key market barriers for heat pump water heater technologies.[19] Heat pump adopters were asked about when they became aware of the technology, and just over half (52%) indicated familiarity with the technology prior to start of the project (Figure 4-7).

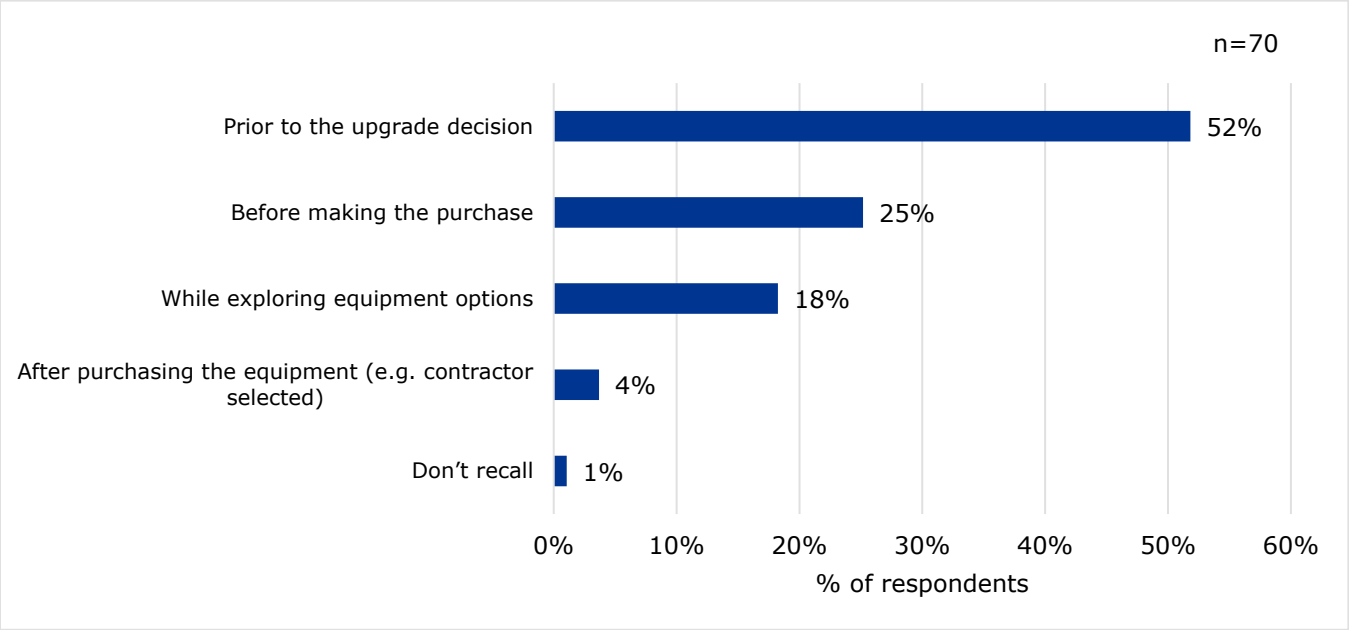
[16] These appendices contain All Things Reported (ATR) tables.

[17] This excludes central system water heaters and water heating controls, which are only applicable to multifamily dwellings.

[18] There is some evidence based on survey responses that participants installing heat pump water heaters under the PA programs may have marginally higher levels of educational attainment and household income, but these differences are not statistically significant.

[19] These market barriers that were identified in a 2013 study surfaced in a 2016 follow up as well, suggesting that there haven't been major shifts in such market barriers. https://neep.org/sites/default/files/NEEP_ASHP_2016MTStrategy_Report_FINAL.pdf

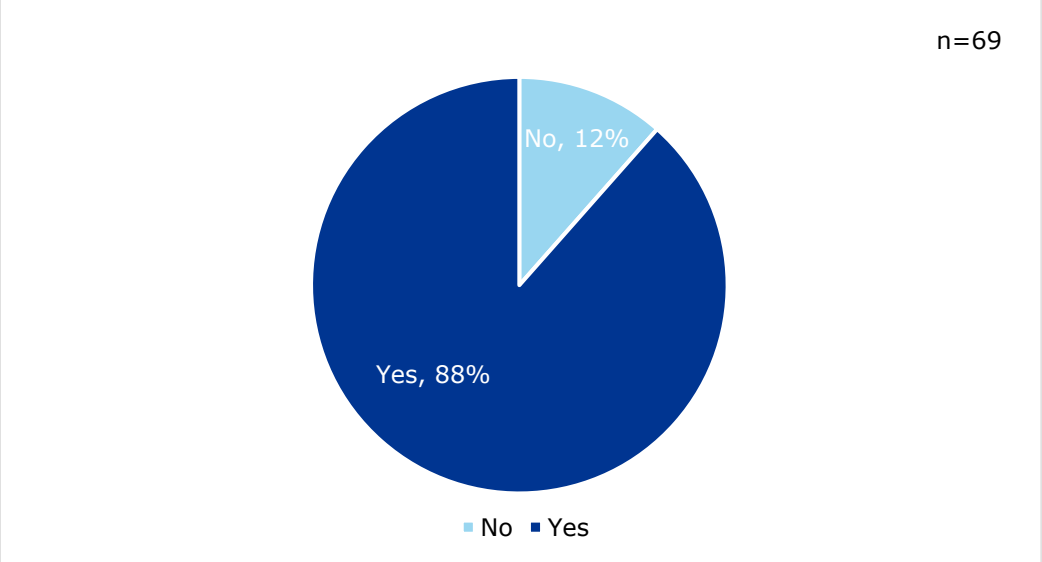
Figure 4-7. When heat pump water-heater adopter became aware of the technology



4.3.9.2 Heat pump costs

Customers installing heat pumps through PA programs indicate a recognition that the technology has higher first-costs, which has been identified as a key market barrier (Figure 4-8). Utility rebates are designed to overcome this specific market barrier and we see the market transformation impacts of these rebates reflected in the stated motivations for measure installation (summarized previously in Figure 4-4), with 65% of all heat pump adopters stating that utility rebates were a key motivation in their decision to install heat pump waters.

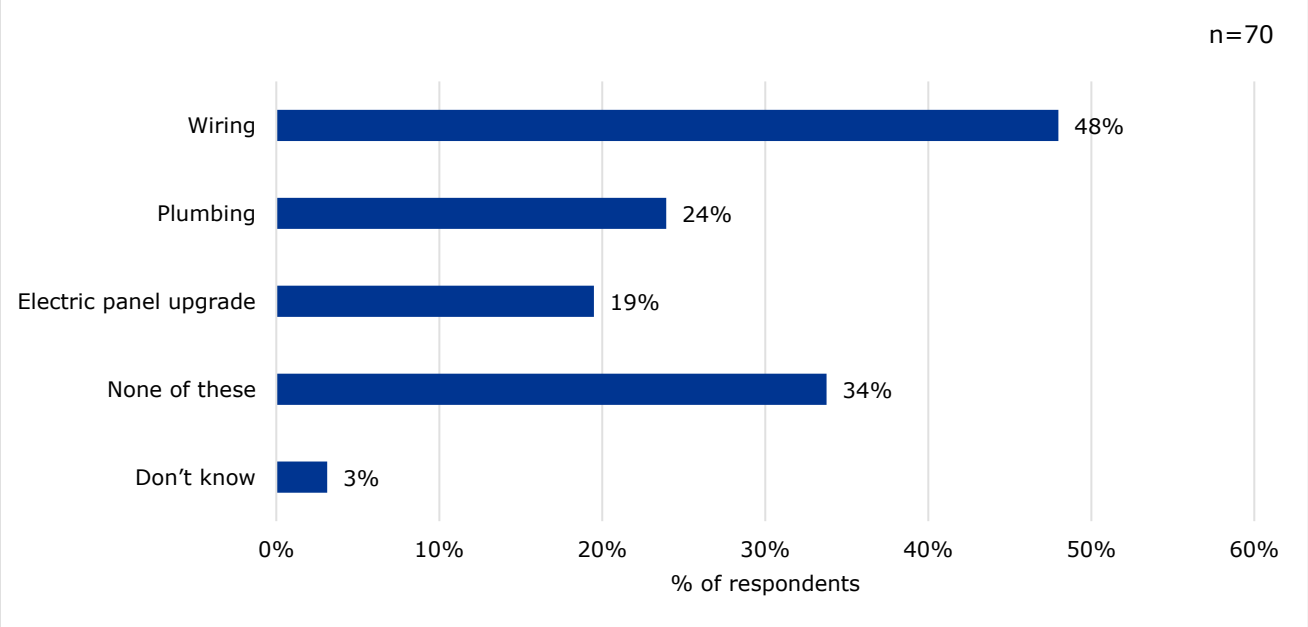
Figure 4-8. Expectation of paying more for heat pumps



Respondents were asked about additional costs incurred to support heat pump adoption. While approximately one-third of all heat pump adopters (35%) indicated that they did not incur additional costs, the remainder

indicated they had additional expense for wiring, plumbing, and electrical panel upgrades (Figure 4-9). Nearly one-fifth (19%) of heat pump adopters indicated that they had to undertake an electrical panel upgrade. A scan of the third-party platform HomeAdvisor, which connects homeowners to home service professionals to perform home projects, shows that costs to replace an electrical panel average around $1,138, with a typical range of $498 to $1,781.[20] Programs should address these often-hidden costs such as panel upgrades, with additional education and incentives for customers and the contractors that serve them. We recommend revisiting the cost-benefit analysis for this measure to account for these customer barriers and potential additional program costs to fully overcome the same.

Figure 4-9. Upgrades required to support heat pump water-heater installation

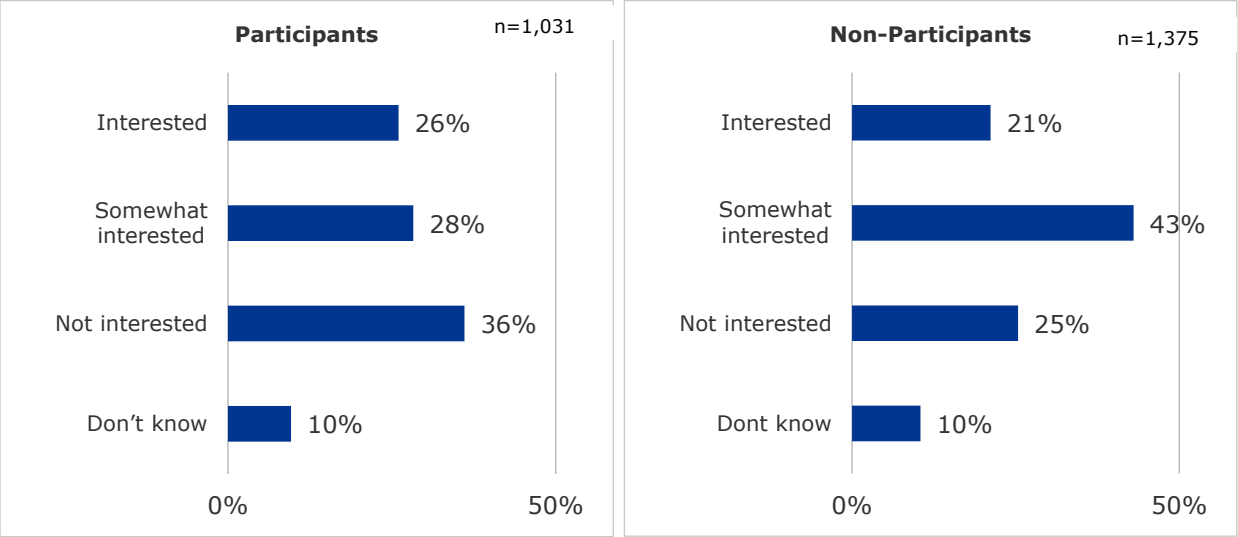


4.3.10 Demand response

Given the peak load reduction potential of water heater demand response programs, we asked respondents to indicate their willingness to participate in such programs. While approximately one-third (36%) of participants and one-quarter (25%) of non-participants are not interested, the majority of participants (54%) and non-participants (64%) indicate some level of interest in participating in water-heater demand response programs and represent potential peak load-shifting opportunity for utilities (Figure 4-10).

[20] https://www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/

Figure 4-10. Interest in water-heater demand response programs



4.3.11 Unit energy consumption and unit energy savings

Although this study does not undertake consumption or end-use metering data analysis to evaluate energy savings of water heater measures installed, we did undertake reasonableness checks of the claimed unit energy savings of the measures as described in this section.

An examination of the dwelling type mix from the participant and non-participant surveys for PY2019 reveals that 90%-100% of participants (occupant decision makers) who responded to the survey are from single-family residences compared to 60%-77% of 2019 Residential Appliance Saturation Survey (RASS) respondents. The unit energy consumption (UEC)[21] of electric and gas water heating for participants may be approximated by the 2019 RASS estimate for single-family at 2,384 kWh and 260 therms respectively (Table 4-8).

Table 4-8. 2019 RASS residence type and water heating UECs versus participant surveys

Dwelling Type	Electric Water Heaters			Gas Water Heaters		
	2019 RASS Dwelling Type Mix	2019 RASS UEC (kWh)	PY2019 Participant Survey Dwelling Type Mix (n=78)	2019 RASS Dwelling Type Mix	2019 RASS UEC (therms)	PY2019 Participant Survey Dwelling Type Mix (n=974)
Single family	60%	2,384	100%	77%	260	97%
Multifamily	39%	1,186	0%	21%	249	3%
Mobile home	1%	2,107	0%	2%	257	0%

Table 4-9 presents the average claimed savings per home (from the tracking data) by equipment type for electric and gas water heaters incentivized by PY2019 programs. For a reasonableness check of the claimed savings values, the electric (kWh) and gas (therm) per unit tracking savings are compared to 2019 RASS water heating end use UECs for single-family homes. High-efficiency natural gas storage and tankless water heater savings are 11% and 19%, respectively, of the 2019 RASS UEC. Average HPWH savings relative to an electric resistance water heater baseline is 68% of the 2019 RASS UEC. For fuel substitution HPWHs, which were not offered as measures for the 2019 programs, the claimed gas "savings" (displaced gas use) is only 68% of the RASS UEC and the new, added electric load (shown as negative savings), is only 58% of the RASS UEC. Because there were

[21] Unit energy consumption values refer to annual energy consumption for the specific end use.

no approved fuel substitution workpapers for PY2019, the savings estimates for this scenario were developed from a currently approved statewide workpaper (SWWH025-02). While the values presented here are high-level gross comparisons with averages across equipment types and climate zones, they could indicate where additional analysis or updates to deemed measure savings may be warranted.

Table 4-9. Average claimed UES as percent of RASS water heating UEC for single-family homes

Equipment Type	Average Electric Water Heaters Savings per Home		Average Gas Water Heaters Savings per Home	
	kWh	% of RASS UEC	therms	% of RASS UEC
2019 RASS single-family water heating UECs	2,384	100%	260	100%
High-efficiency natural gas storage water heater	N/A	N/A	28	11%
Tankless natural gas water heater	N/A	N/A	50	19%
Heat pump water heater (electric resistance baseline)	1,618	68%	N/A	N/A
Heat pump water heater (gas baseline, fuel substitution)	-1,371	-58%	176	68%

4.3.12 Occupant reported hot water use characteristics

Table 4-10 summarizes hot water use patterns from 2019 RASS and the PY2019 participant and non-participant surveys. As noted in section 4.3.1, the participant and non-participant PY2019 survey samples are largely composed of single-family residents (>90%), therefore we compare survey values to 2019 RASS single-family values. Findings presented below could provide additional inputs for the algorithms used to calculate deemed unit energy savings estimates.

Table 4-10. Hot water use profile for non-participants and PY2019 participants

Water Use Characteristics	Electric Water Heaters			Gas Water Heaters		
	2019 RASS Survey (single family)	Non-participants (n=125)	Participants (n=78)	2019 RASS Survey (single family)	Non-participants (n=1,237)	Participants (n=974)
Hot Water Use Behavior						
1 to 3 showers per day	70%	82%	69%	80%	81%	76%
4 or more showers per day	29%	13%	20%	19%	16%	19%
Average number of showers per day	2.8	2.3	2.6	2.4	2.5	2.7
Baths per day - None	83%	76%	87%	89%	75%	81%
Baths per day – 1 or more	17%	24%	19%	11%	25%	26%
Average number of baths per day	0.3	0.7	0.4	0.2	0.7	0.7
Hot Water Use - Settings and Features						
Low-flow showerheads for some or all showers	71%	79%	80%	79%	82%	78%
Water saving aerators for some or all faucets	22%	69%	78%	61%	72%	75%
Percent clothes washer loads with hot/warm water	68%	58%	60%	58%	59%	63%
Have a dishwasher	69%	85%	89%	76%	89%	85%
Average number of dishwasher loads per week	1.0	2.7	2.9	2.6	2.8	2.3
Household Characteristics						

Water Use Characteristics	Electric Water Heaters			Gas Water Heaters		
	2019 RASS Survey (single family)	Non-participants (n=125)	Participants (n=78)	2019 RASS Survey (single family)	Non-participants (n=1,237)	Participants (n=974)
Average number of residents	3.2	2.6	2.7	3.1	2.9	2.9
Dwelling size: greater than 2,000 square feet	45%	37%	48%	36%	36%	47%
Dwelling vintage: Pre-2000	93%	74%	92%	88%	80%	82%

Multifamily. While the table above summarizes responses that also include a small proportion of multifamily occupants from the PY2019 surveys, property manager surveys provide an additional perspective on hot water use in multifamily homes. Over 90% of property managers (n=102, property manager results are not shown in tables) indicate that water saving measures such as low-flow showerheads and faucet aerators are installed in some or all dwelling units of their properties. This points to a higher penetration of these water saving measures in multifamily properties.

Opportunity for deeper savings. Only 12% of property managers state that their hot water pipes are insulated and a mere 3% state that their water heater is installed in an insulated space. The occupant surveys indicate that 20% and 19% of non-participants and 28% and 17% of participants have insulated their hot water pipes and installed their water heater in an insulated space respectively (Table 4-11). While the participant and non-participant survey respondents, who are mainly single-family occupants, report pipe insulation and installation of water heating equipment in conditioned spaces, there is potential for deeper savings with both single and multifamily dwellings when it comes to water heater installation practices. We summarize results related to additional factors that impact water heater unit-energy savings from the non-participant and participant surveys below.

Table 4-11. Additional factors that impact water heater unit energy savings

Water Use Characteristics	Non-participants (n=1,375)	All Participants (n=1,052)
Homes with two or more bathrooms in home	92%	95%
Homes with seven or more faucets in home	21%	25%
Average number of bathrooms	2.5	2.7
Average number of faucets	5.0	5.3
Homes with hot water pipes insulated	20%	28%
Homes where water heaters located in conditioned space	19%	17%
Homes with an ENERGY STAR dishwasher	57%	70%
Homes with an ENERGY STAR clothes washer	70%	81%
Homes with an ENERGY STAR water heater	49%	91%
Homes with no ENERGY STAR appliance	6%	1%

4.4 Non-participant survey results

We present further details on findings from the non-participant survey and differences by PA in the section below.

4.4.1 Demographic profile of non-participants by PA

Table 4-12 displays demographic characteristics of non-participants. Relative to the other PAs, PG&E customers were more likely to have homes built before 1980 and to have household incomes greater than $100,000.

SDG&E customers were more likely to be white and have seniors living in the home. SCE customers tended to have to have more residents per home, more young children in the home, and were more likely to have homes built in 2000 or later. SCG customers were more likely to have non-English speaking households, identify as Hispanic, have less than a bachelor's degree, and less likely to have household incomes greater than $100,000.

Table 4-12. Demographic profile of non-participant respondents by PA

Demographic Characteristics	PG&E [a] (n=924)[22]	SDG&E [b] (n=215)	SCE [c] (n=157)	SCG [d] (n=79)	Total (n=1,375)
Dwelling Type					
Single family	93%[b]	89%[a]	92%	92%	92%
Multifamily	6%	7%	6%	5%	6%
Mobile Home	1%	3%	2%	3%	2%
Dwelling Vintage					
Before 1980	52%[b,c]	45%[a]	37%[a,d]	55%[c]	49%
1980-1999	27%[b,d]	36% [a,d]	33% [d]	17%[a,b,c]	29%
2000 and later	20%[c]	18%[c]	30%[a,b]	23%	21%
Don't know	1%	1%	1%	5%	1%
Dwelling Size					
Less than 1,000 square feet	6%	8%	8%	11%	7%
1,000 to 2,000 square feet	55%	57%	55%	51%	55%
Greater than 2,000 square feet	36%	34%	34%	35%	36%
Don't know	2%	0%	3%	4%	2%
Household Composition					
Average number in household	2.8[c]	2.7[c]	3.1[a,b]	2.9	2.8
% Age 5 and under	13%[b,c]	8%[a,c,d]	22%[a,b]	20%[b]	14%
% Age 65 and over (seniors)	40%[b,c]	47%[a,c,d]	26%[a,b]	32%[b]	39%
Language					
% Non-English primary language	8%[b]	5%[a,d]	7%	13%[b]	8%
Ethnicity					
% Hispanic/Latino/Spanish	9%[c,d]	11%[d]	14%[a,d]	28%[a,b,c]	11%
Race					
% White	62%[b,c]	73%[a,c,d]	51%[a,b]	62%[b]	62%
% Black	2%	1%	1%	1%	2%
% Other	20%[b,d]	11%[a,c]	20%[b]	12%[a]	18%
Refused	16%	16%	27%	25%	18%
Education					
Lower than Bachelor's	26%[d]	29%[d]	25%[d]	41%[a,b,c]	27%
Bachelor's	34%	35%	35%	26%	34%
Higher than Bachelor's	35%	32%	29%	29%	33%
Refused	5%	4%	11%	5%	6%

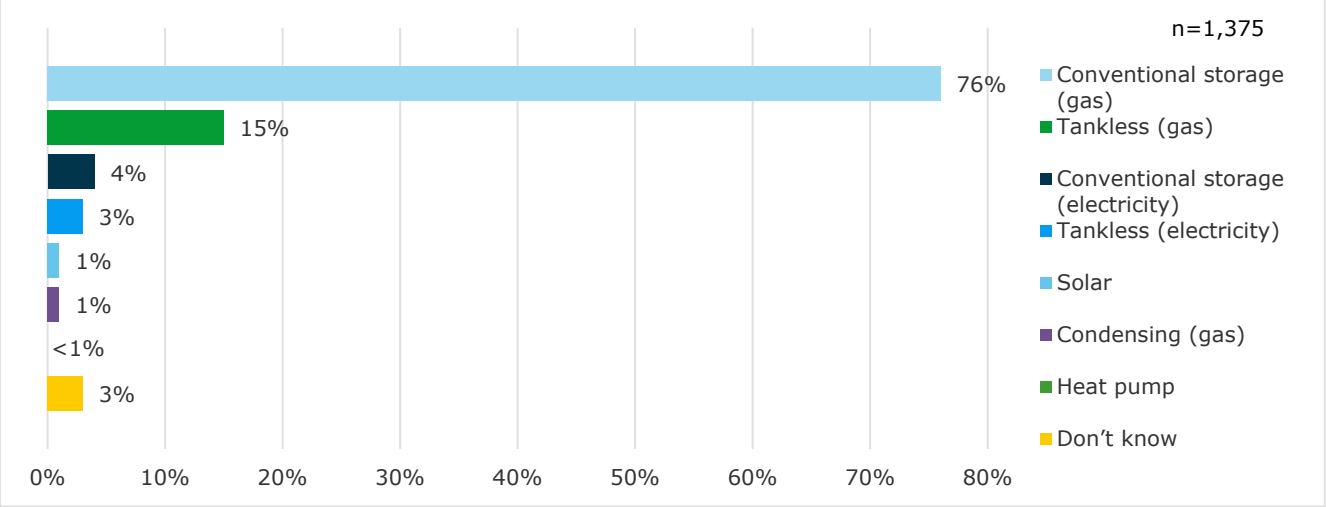
[22] The comparison made in the above are between PG&E, SDG&E, SCE, and SCG. The four groups in the table are denoted by the letters a, b, c, and d by order of appearance from left to right. Superscripted letters indicate that statistic displayed in the cell is significantly different from the corresponding group denoted by superscript.

Demographic Characteristics	PG&E [a] (n=924)[22]	SDG&E [b] (n=215)	SCE [c] (n=157)	SCG [d] (n=79)	Total (n=1,375)
Income					
Less than $50,000	11%	9%[d]	13%	17%[b]	11%
$50,000 - $100,000	19%[b,d]	26%[a,c]	18%[b,d]	29%[a,b,c]	21%
Greater than $100,000	41%[b,d]	35%[a,d]	35%[d]	24%[a,b,c]	38%
Refused	29%	29%	33%	29%	30%

4.4.2 Existing water heater technology

The majority (91%) of non-participants' water heaters were fueled by gas, including conventional storage gas (76%) and tankless gas (15%) water heaters (Figure 4-11). There were no significant differences between PAs with respect to water heater fuel type. Only 1% of non-participants' water heaters were solar or condensing gas, and less than 1% were heat pump water heaters. Around 3% of non-participants had more than one water heater. Water heater types did not differ significantly by factors such as income, education, or household size.

Figure 4-11. Water heater type

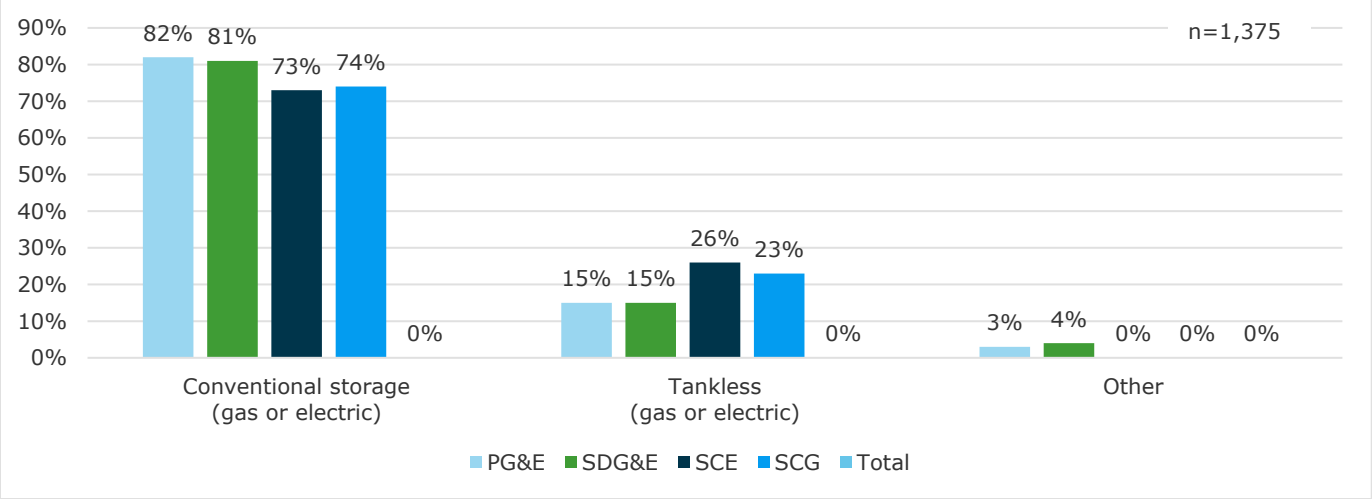


Note.
Percentages may not add up to 100%

Four-fifths (80%) of non-participants' water heaters were conventional storage (gas or electric, Figure 4-12). SCE customers were less likely to have conventional storage (73%) and more likely to have tankless (26%) than PG&E (82%, 15%) and SDG&E (81%, 15%) customers respectively. These differences were statistically significant.[23]

[23] Statistical significance test results reported at 90% level of confidence and 10% level of significance.

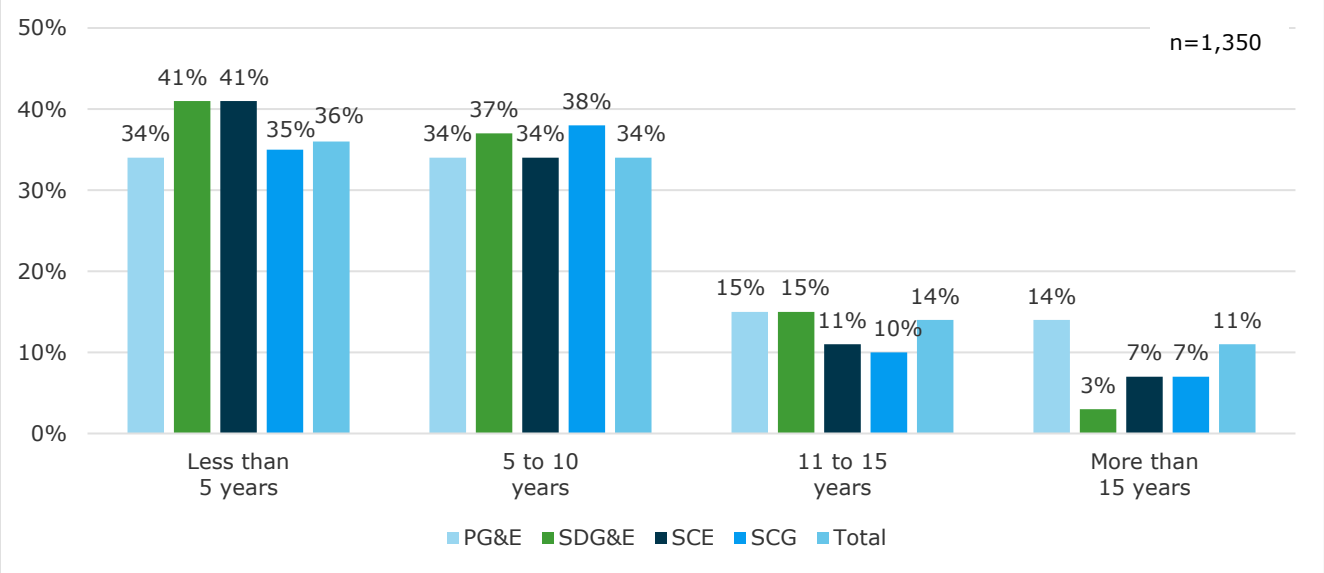
Figure 4-12. Water heater type by PA



Note. Percentages may not add up to 100%

Age of water heaters. One-quarter (25%) of non-participants' water heaters were more than 10 years old (Figure 4-13). PG&E customers were more likely to have water heaters over 10 years old (29%) than SDG&E (18%), SCE (18%), and SCG (17%) customers. These differences were statistically significant.

Figure 4-13. Water heater age by PA



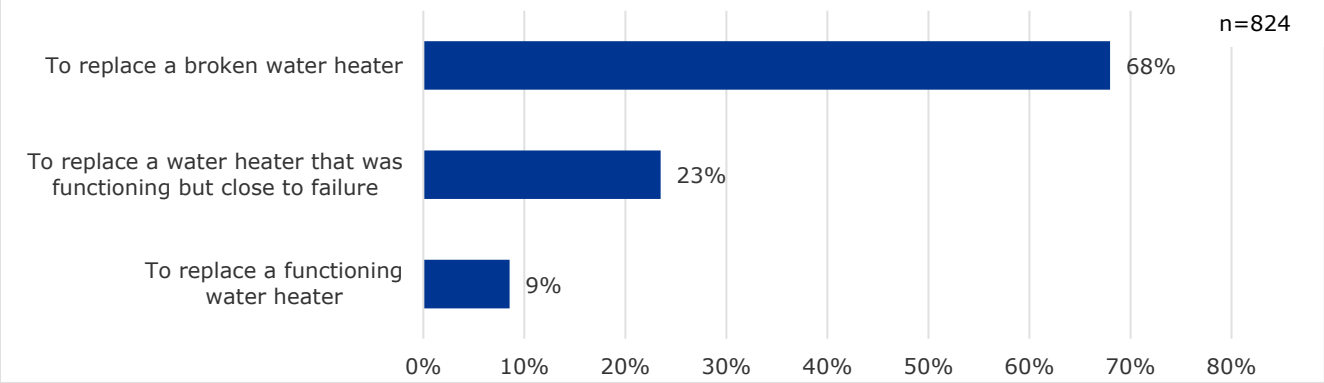
Note. Percentages may not add up to 100%. 7% of non-participants did not know the age of their water heater.

Around 60% of non-participants had installed their current water heater to replace an old one (Figure 4-14).[24] Most of these installations were to replace a broken water heater (68%) or a water heater that was functioning

[24] The rest of the non-participants said their current water heater was installed before they moved in or their home was newly constructed without an existing water heater.

but close to failure (23%). Just under one in ten (9%) were to replace a functioning water heater (i.e., early replacement). There were no significant differences between PAs with respect to early replacement.

Figure 4-14. Reason for replacing previous water heater

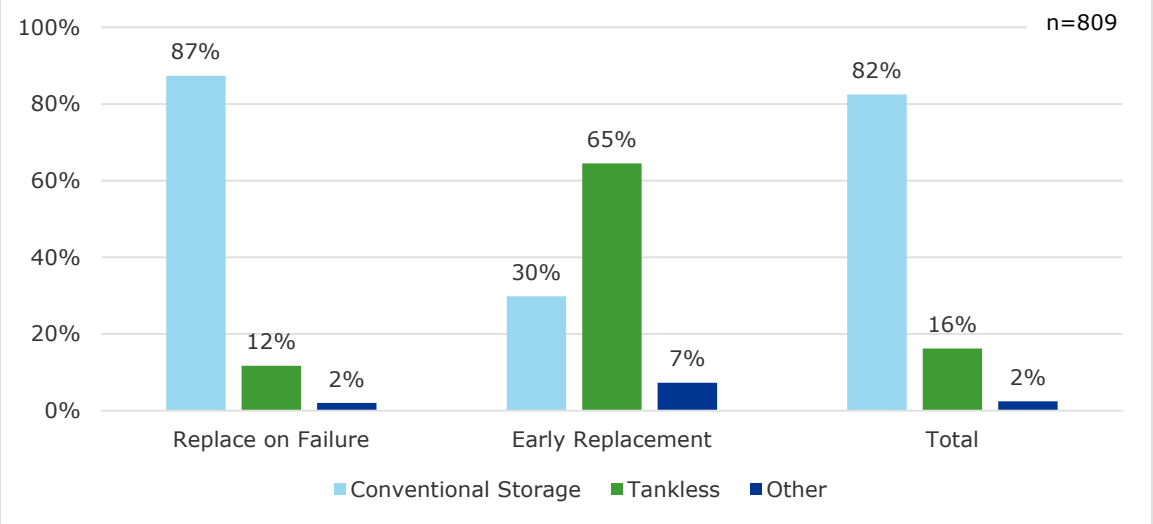


Note that 15% of the water heaters included in the figure above were replaced more than ten years.

Figure 4-15 shows the type of water heater non-participants installed by the reason for replacement. Other water heater types in the figure include heat pump, solar, and condensing gas water heaters. Non-participants who had replaced a water heater upon failure were more likely to have installed a conventional storage water heater (87%) than those who had replaced a functioning water heater (30%), and were less likely to have installed a more efficient tankless water heater (12% versus 65%). These differences were statistically significant at the 90% confidence level.

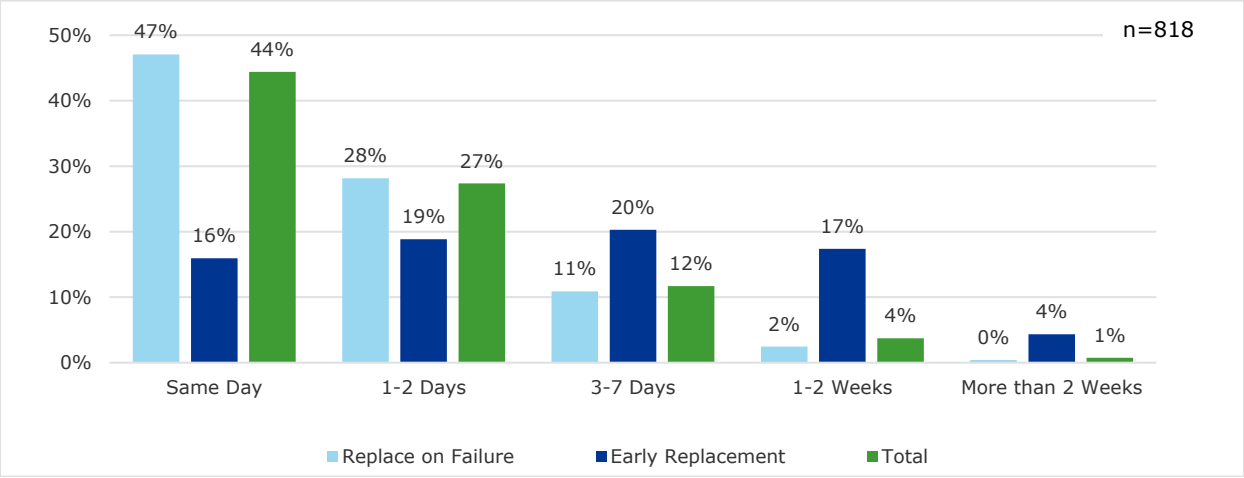
They were also more likely to install other, efficient types of water heaters in early replacement scenarios (7%) compared to replacement on failure scenarios (2%), although this difference is not statistically significant at the 90% confidence level.

Figure 4-15. Reason for replacing previous water heater by current water heater type



Over 44% of non-participants who had to replace a water heater received the new one the same day they ordered it (Figure 4-16). Not surprisingly, non-participants who replaced their water heaters early waited longer to receive their new water heaters (4.9 days on average) than non-participants whose water heaters had failed or were close to failure (1.4 days on average, difference statistically significant at the 90% confidence level).

Figure 4-16. Length of wait for new water heater



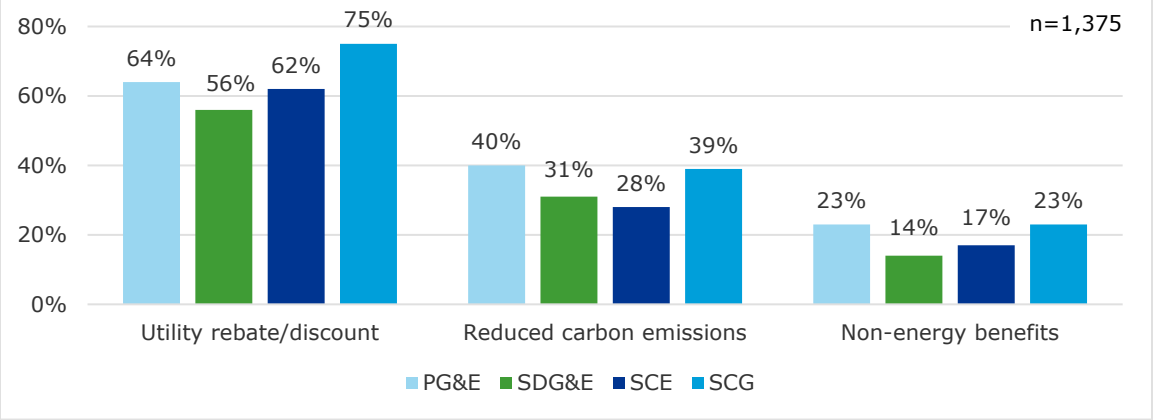
Note that 15% of the water heaters included in the figure above were replaced more than ten years ago.

4.4.3 Motivations of water heater equipment installation for non-participants by PA

As we indicated in section 4.3.5, when asked to indicate what their motivators for water heater replacement would be, the factors non-participants identified as most likely to influence their water heater purchase decisions were reducing energy bills (69%), utility rebates/discounts (63%), and equipment failure (53%). In addition, over one-third of non-participants said reducing carbon emissions (37%) and the water heater needing maintenance (35%) would influence their purchase decisions.

Figure 4-17 displays non-participant response differences on factors that would motivate water heater replacements among PAs, including utility rebates/discounts, reduced carbon emissions, and non-energy benefits. SCG customers were more likely to cite a utility rebate/discount (75%) as a factor than PG&E (64%), SDG&E (56%), and SCE (62%) customers. PG&E and SCG customers were more likely to cite reducing carbon emissions (40% and 39%, respectively) than SCE customers (28%). PG&E and SCG customers were more likely to cite non-energy benefits (23%) than SDG&E customers (14%). These differences were statistically significant at the 90% confidence level.

Figure 4-17. Factors influencing water heater purchase decision by PA



The team asked non-participants if they would replace or upgrade their current water heater even if it were in working condition. Ten percent of non-participants said 'yes,' while an additional 44% said 'maybe' (Figure 4-18).

Figure 4-18. Would consider replacing a working water heater

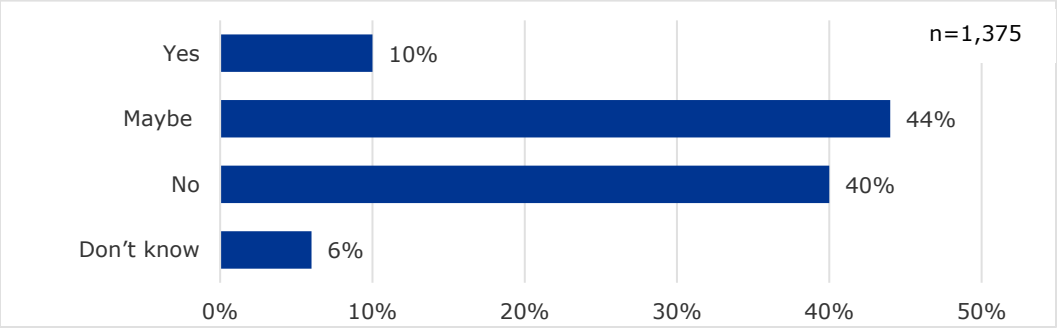
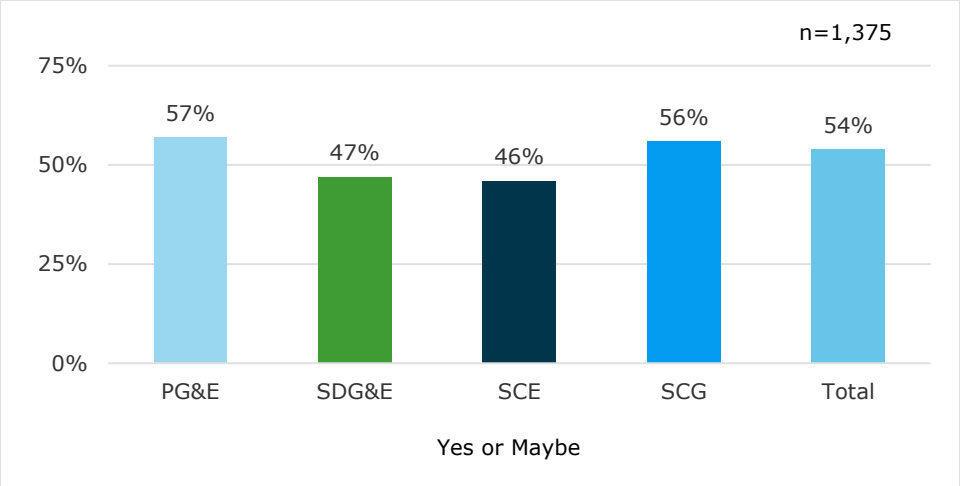


Figure 4-19 shows the percent of non-participants who said 'yes' or 'maybe' to replacing or upgrading their current water heater if it were in working condition by PA. PG&E (57%) and SCG (56%) customers were more likely to say 'yes' or 'maybe' to replacing a working water heater than SDG&E (47%) and SCE customers (46%). However, only the differences between PG&E (57%) and SDG&E (47%), and PG&E (57%) and SCE (46%) were statistically significant at the 90% confidence level.

Figure 4-19. Would consider replacing a working water heater by PA



4.4.4 Awareness of water heater technologies

Figure 4-20 displays the percent of non-participants aware of different water heater technologies. Most non-participants had heard of conventional storage and tankless water heaters (92% and 84%, respectively). Around one-half (48%) of non-participants had heard of solar water heaters. Less than one-third (28%) of non-participants had heard of heat pump water heaters and only 11% had heard of condensing gas water heaters.

Figure 4-20. Awareness of water heater technologies

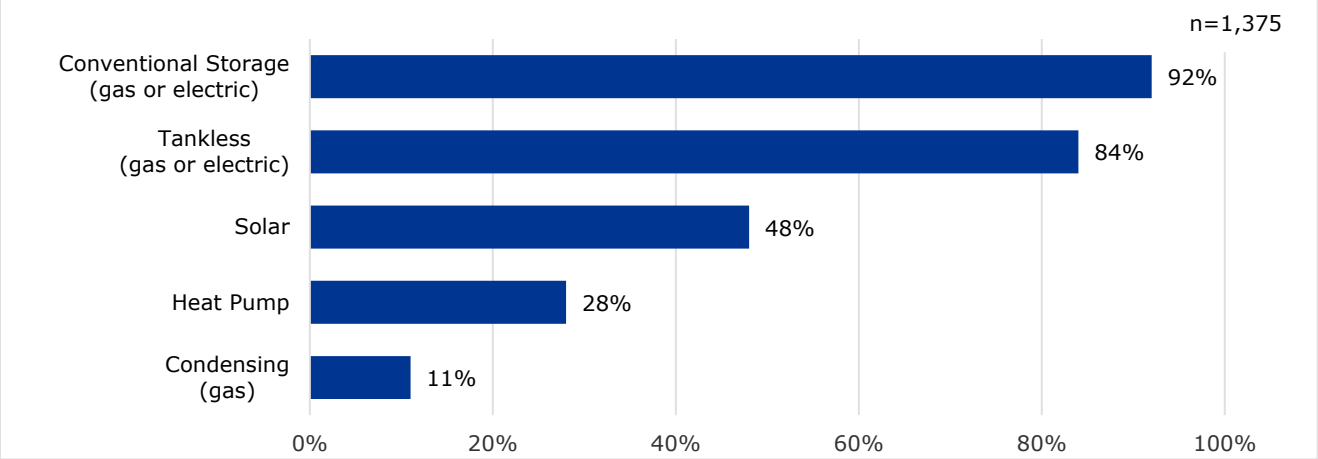


Figure 4-21 illustrates non-participant awareness of water heater technologies by PA. PG&E and SDG&E customers were more likely to have heard of heat pump water heaters (31% and 29%, respectively) than SCE (18%) or SCG (17%) customers. PG&E and SDG&E customers were also more likely to have heard of solar water heaters (51%) than SCE customers (35%). These differences were statistically significant at the 90% confidence level.

Figure 4-21. Awareness of water heater technologies by PA

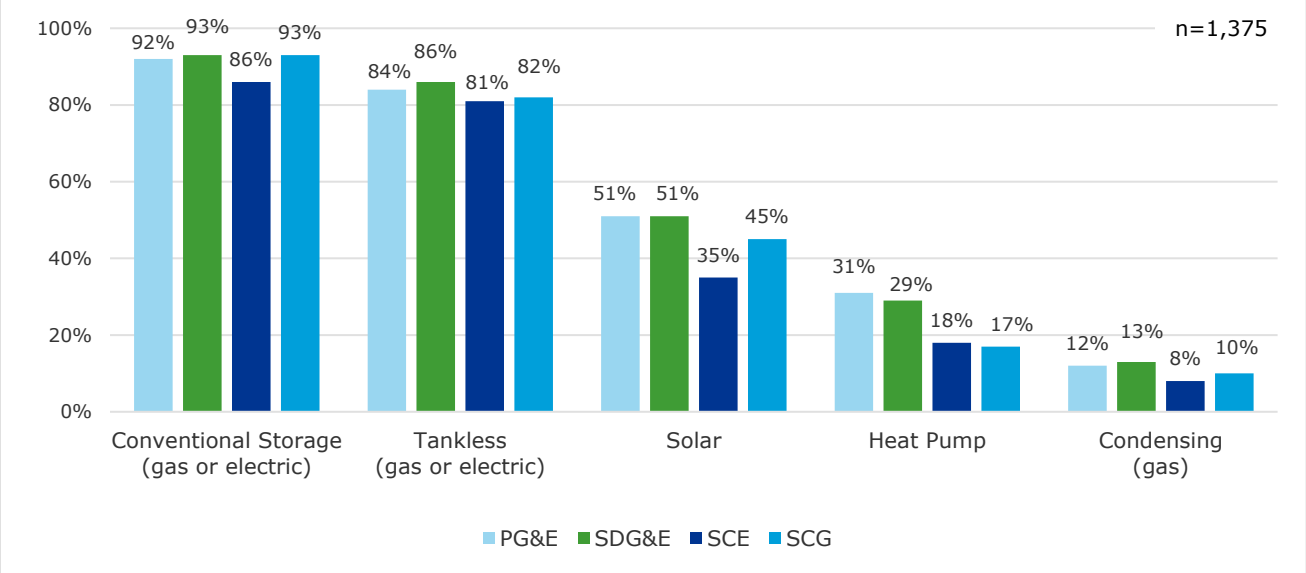


Figure 4-22 and Figure 4-23 display non-participant awareness of water heater technologies by income and education, respectively. With the exception of condensing gas boilers, awareness of all water heater technologies increased with income[25] and education.[26]

Figure 4-22. Awareness of water heater technologies by income

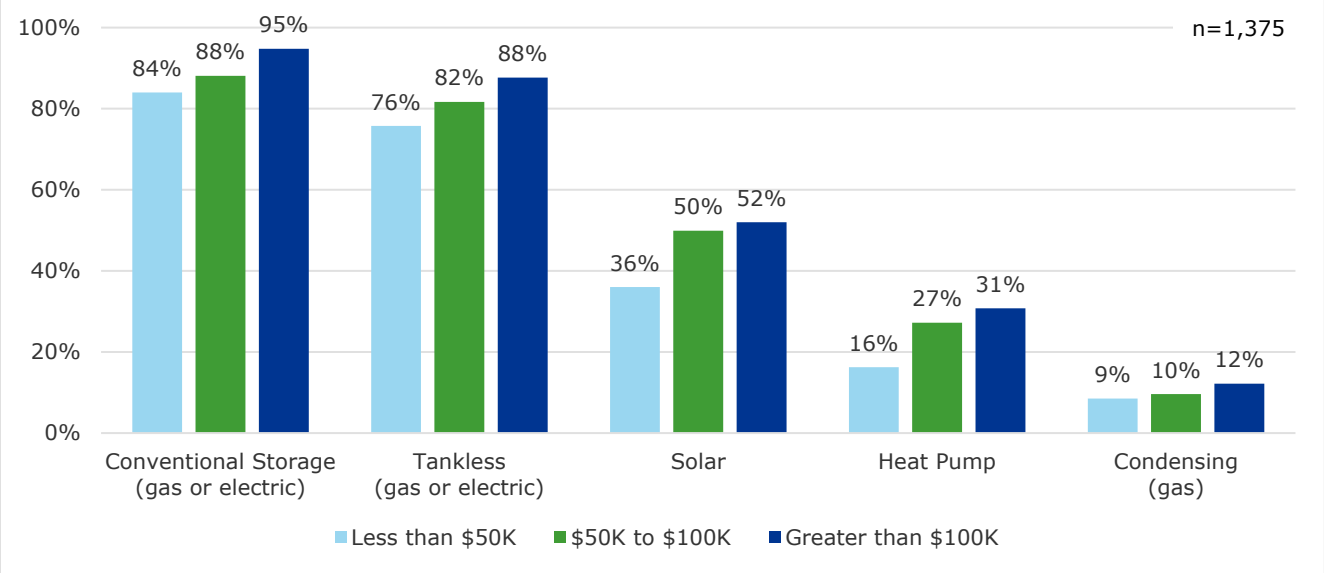
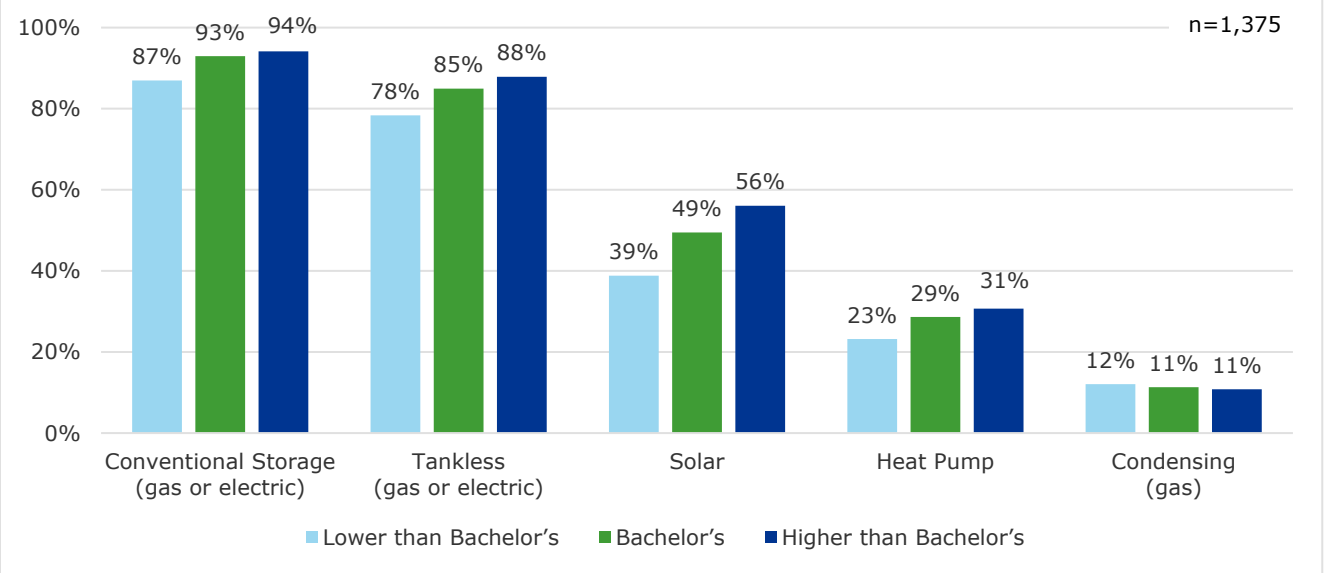


Figure 4-23. Awareness of water heater technologies by education



Our team asked non-participants how likely they would be to consider certain types of water heaters using a 5-point scale, where 1 was "not at all likely to consider" and 5 was "very likely to consider." Around two-thirds of non-participants indicated they were likely to consider conventional storage (66%) and tankless water heaters (65%) by assigning a rating of 4 or 5 (Figure 4-24). Less than one-third (29%) of non-participants were likely to

[25] Differences between Less than $50K and Greater than $100K are statistically significant at the 90% confidence level for all technologies except condensing gas.

[26] Differences between Lower than Bachelor's and Higher than Bachelor's are statistically significant at the 90% confidence level for all technologies except condensing gas.

consider solar water heaters, and less than one-fifth were likely to consider heat pump (17%) and condensing gas (13%) water heaters. Customer willingness to consider the various types of water heaters did not differ significantly between PAs.

Figure 4-24. Likelihood to consider water heater type

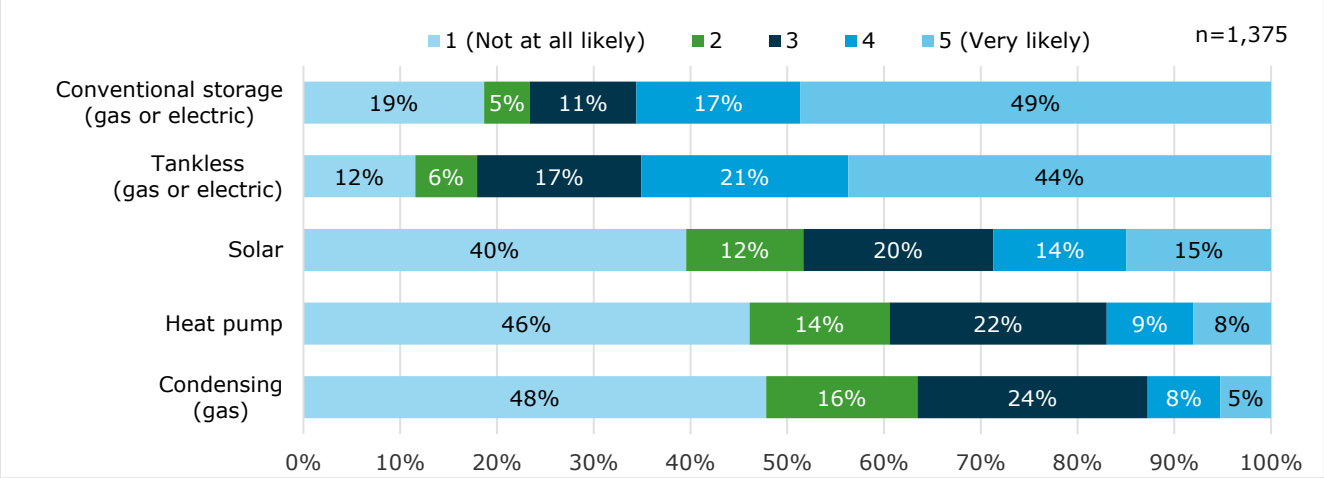
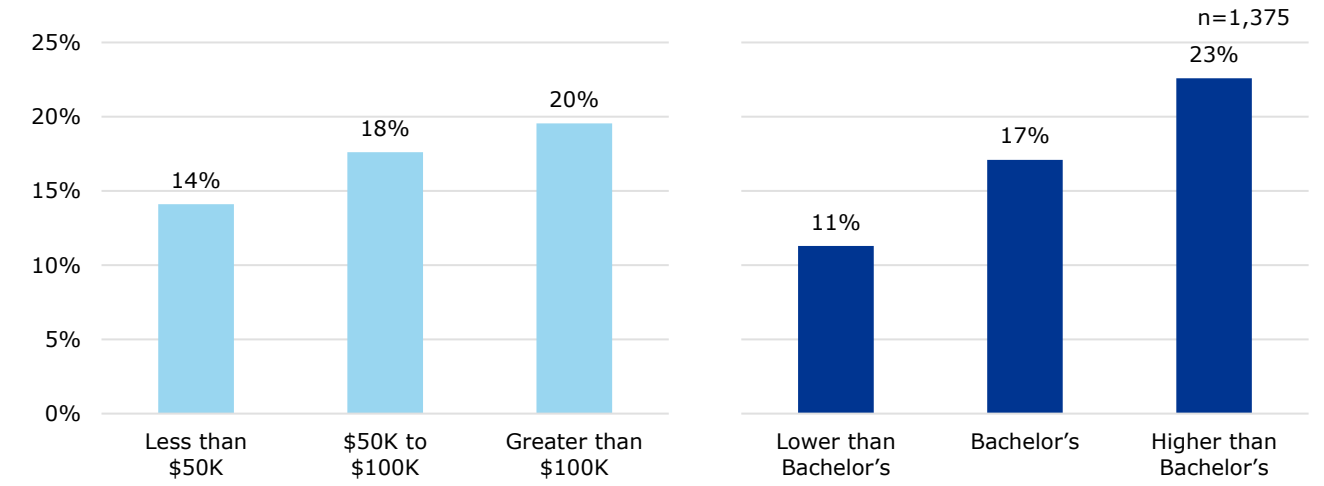


Figure 4-25 shows the percent of non-participants who assigned a likelihood rating of 4 or 5 (somewhat or very likely) for heat pump water heaters by income and education. The likelihood to consider a heat pump water heater increased with income[27] and education.[28]

Figure 4-25. Somewhat or very likely to consider heat pump water heater by income and education



4.4.5 Barriers to water heater adoption

Our team asked non-participants who rated their likelihood of considering a given type of water heater only 1 or 2 to explain why they were unlikely to consider it (Table 4-13). The most common reason for not wanting to install a conventional storage water heater was higher operating cost (46%). The most common reasons for not wanting to install a tankless water heater were higher purchase price (35%) and the cost to upgrade wiring,

[27] Difference between Less than $50K and Greater than $100K is statistically significant at the 90% confidence level.
[28] Difference between Lower than Bachelor's and Higher than Bachelor's is statistically significant at the 90% confidence level.

electrical panel, or plumbing (32%). The most common reason for not wanting to install a heat pump or condensing gas water heater was unfamiliarity with the technology (48% and 64%, respectively). The most common reason for not wanting to install a solar water heater was not having solar panels and not planning to install them (38%).

Table 4-13. Reasons unlikely to consider water heater type

Reason	Conventional storage (gas or electric) (n=310)	Tankless (gas or electric) (n=251)	Heat Pump (n=840)	Solar (n=709)	Condensing (gas) (n=885)
Unfamiliar with the technology	6%	18%	48%	25%	64%
Higher purchase price	9%	35%	20%	23%	9%
Higher cost to operate	46%	17%	21%	5%	6%
Cost to upgrade wiring, electrical panel, or plumbing	9%	32%	21%	23%	8%
Structural limitations	27%	19%	8%	21%	7%
I wouldn't want to change water heater types	27%	14%	14%	13%	12%
I prefer "tried-and-true" water heaters to newer water heater technologies	0%	13%	10%	9%	8%
I don't have solar panels and don't have plans to install them	0%	0%	0%	38%	0%
Don't plan on living in the home long enough to reap the benefits	2%	8%	8%	11%	6%
Does not work well	2%	5%	0%	1%	0%
Not good for large families	1%	2%	3%	0%	0%
Not energy efficient	5%	0%	0%	0%	0%
Not eco-friendly	2%	0%	0%	0%	0%
Other	3%	3%	4%	4%	1%
Don't know	4%	8%	10%	6%	12%

Our team asked non-participants whose existing water heater was fueled by gas what barriers or challenges would prevent them from replacing a gas water heater with an electric one. Figure 4-26 shows the most frequently mentioned barrier was operating cost (47%), followed by existing equipment still being in good condition (34%), purchase price (33%), and panel upgrade requirements (29%). In addition, one-quarter (25%) of non-participants with gas water heaters had a personal preference for gas over electric.

Figure 4-26. Barriers to replacing gas with electric

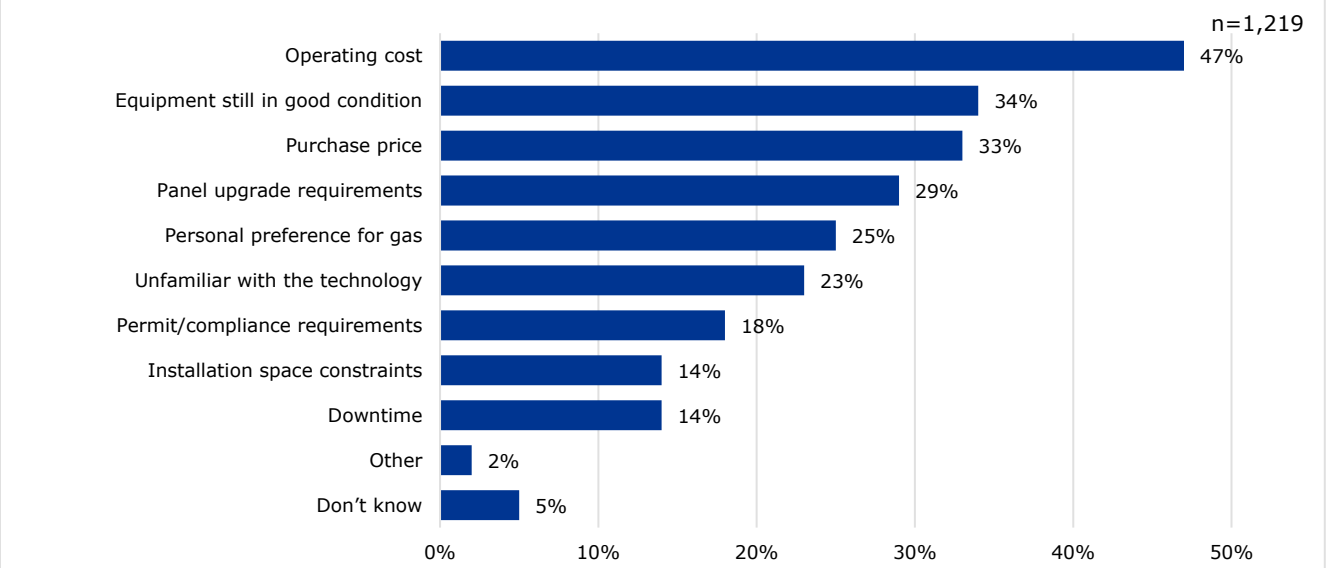
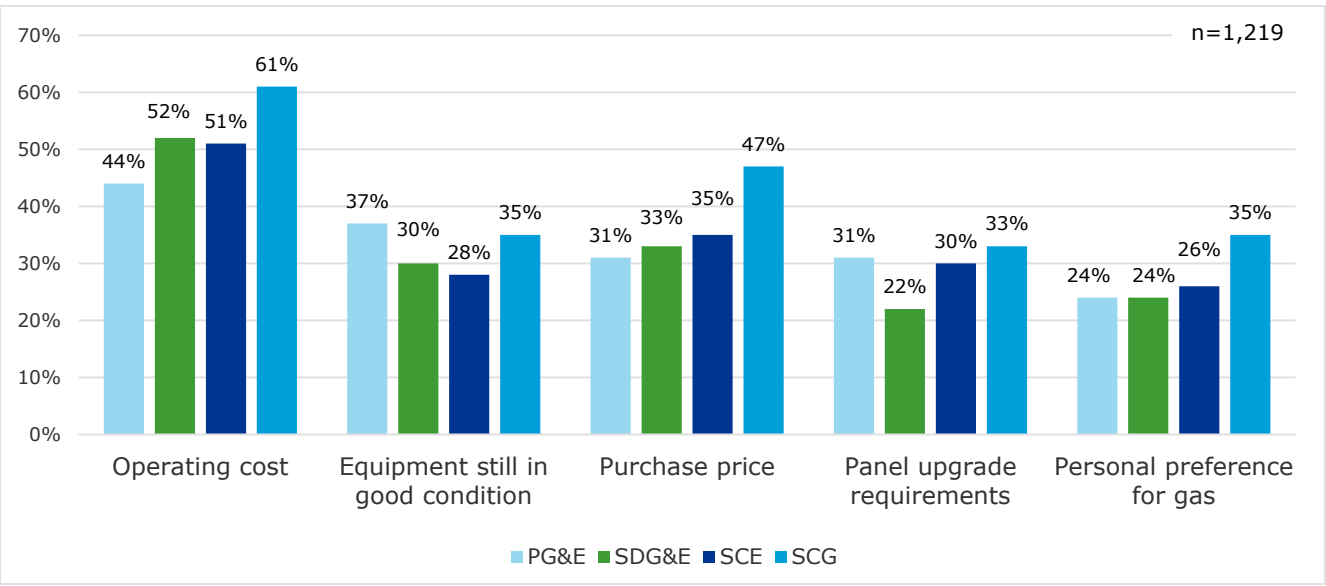


Figure 4-27 displays the barriers preventing non-participants from replacing a gas water heater with an electric one by PA. PG&E customers were less likely to cite operating cost (44%) than SDG&E and SCG customers (52% and 61%, respectively). PG&E customers were more likely to mention existing equipment still being in good condition (37%) than SDG&E and SCE customers (30% and 28%, respectively). SCG customers were more likely to mention purchase price (47%) than PG&E (31%), SDG&E (33%), and SCE (35%) customers. SDG&E customers were less likely to mention panel upgrade requirements (22%) than PG&E and SCG customers (31% and 33%, respectively). SCG customers were more likely to have a personal preference for gas (35%) than PG&E and SDG&E customers (24%). These differences were statistically significant at the 90% confidence level.

Figure 4-27. Barriers to replacing gas with electric by PA



Our team asked non-participants if they would consider purchasing a $3,000 high-efficiency water heater instead of a $1,000 standard-efficiency water heater if the efficient model cost $330 less to run per year. Figure 4-28

shows that 16% of non-participants said they would purchase the high-efficiency model with no utility rebate/discount. The percent of non-participants who said they would purchase the high-efficiency model with no utility rebate/discount was not significantly different between PAs.

Figure 4-28. Would consider high efficiency water heater without incentive and with 15% lower operating cost per year

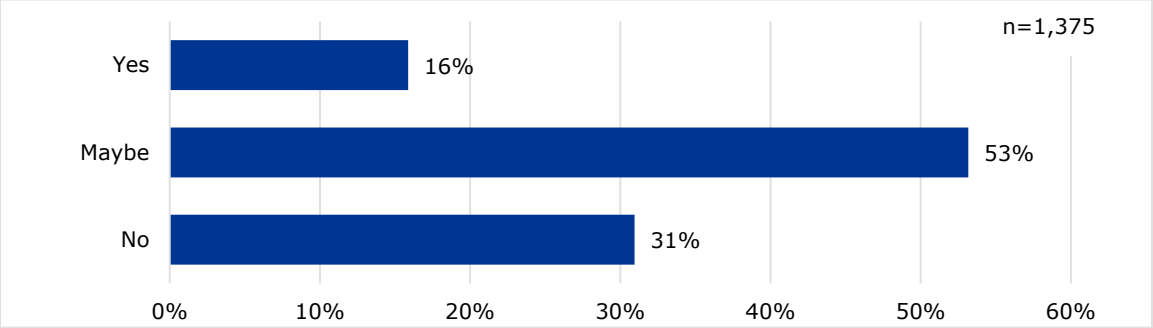
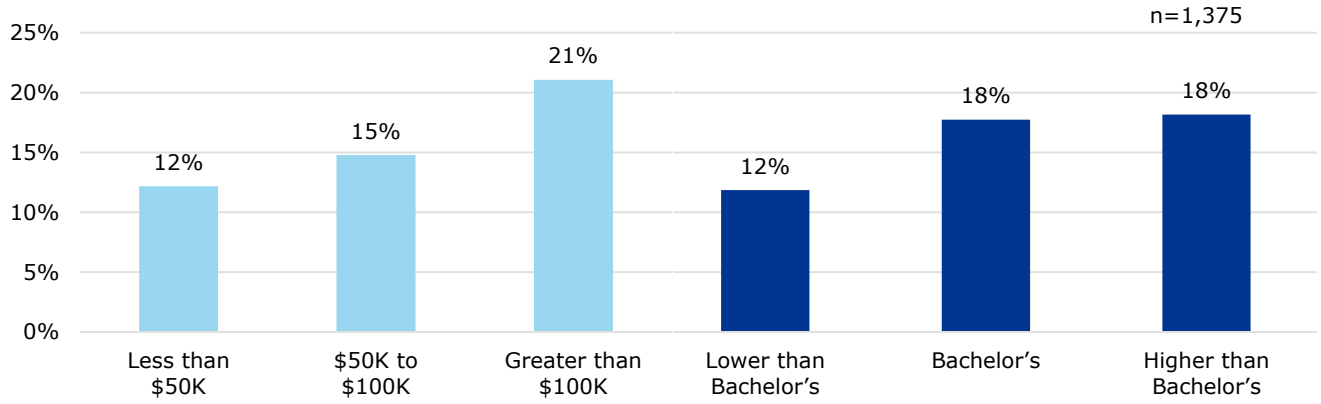


Figure 4-29 shows the percent of non-participants who said they would purchase the high-efficiency model with no utility rebate/discount by income and education. Willingness to purchase the high-efficiency model with no utility rebate/discount increased with income[29] and education.[30]

Figure 4-29. Would consider high-efficiency water heater without incentive by income and education

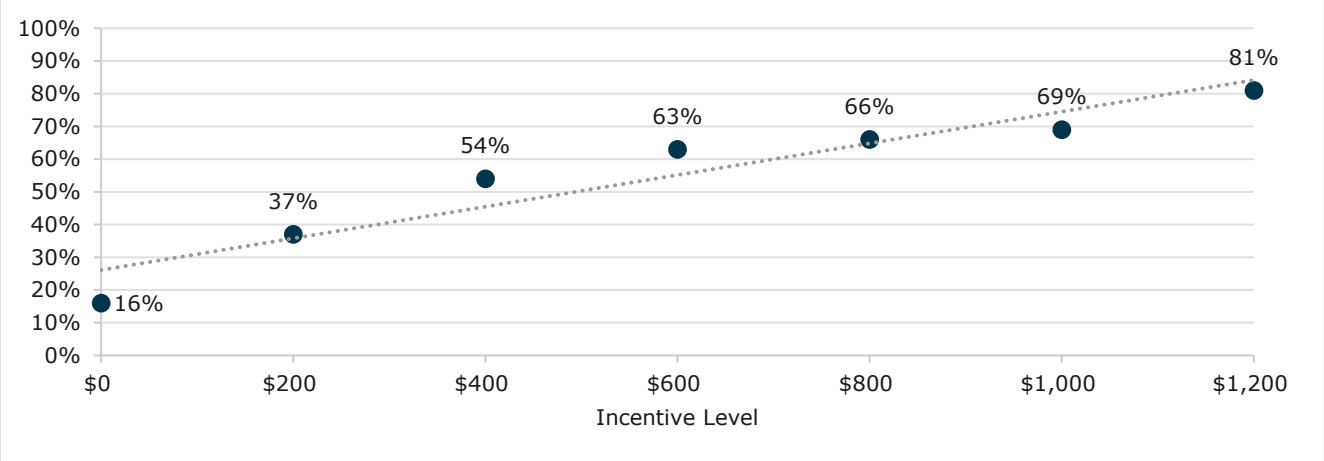


We randomly assigned non-participants to one of six groups and asked each group if they would consider purchasing the high efficiency model with a specific incentive amount: either $200, $400, $600, $800, $1,000, or $1,200. Figure 4-30 displays the percent of non-participants who said they would purchase the high efficiency model at each incentive level. Only 16% of non-participants said they would purchase the high efficiency model with no incentive. Over four-fifths (81%) said they would purchase the high efficiency model with a $1,200 incentive. For every $100 increase in the incentive level, the probability of purchasing the high efficiency model increased by 4.8 percentage points. At the $400 incentive level, over one-half (54%) of non-participants said they would purchase the high efficiency model. There were diminishing returns after the $600 incentive level. The difference in the percent of non-participants who said they would purchase the high efficiency model with a $600 discount (63%) versus an $800 discount (66%) is not statistically significant at the 90% confidence level. Similarly, the difference between an $800 discount (66%) and a $1,000 discount (69%) is not statistically

[29] Difference between Less than $50K and Greater than $100K is statistically significant at the 90% confidence level.
[30] Difference between Lower than bachelor's and Higher than Bachelor's is statistically significant at the 90% confidence level.

significant. However, the difference between a $1,000 discount (69%) and a $1,200 discount (81%) is statistically significant.

Figure 4-30. Would consider high-efficiency water heater by incentive level



4.4.6 Barriers and enablers of energy-efficiency program participation

Over one-third (36%) of non-participants had participated in an energy-efficiency program offered by their PA (Figure 4-31). SCG customers were less likely to have participated (24%) than PG&E (34%), SDG&E (45%), and SCE (38%) customers. SDG&E customers were more likely to have participated (45%) than PG&E (34%) customers. These differences were statistically significant at the 90% confidence level.

Figure 4-31. Participation in PA energy-efficiency programs

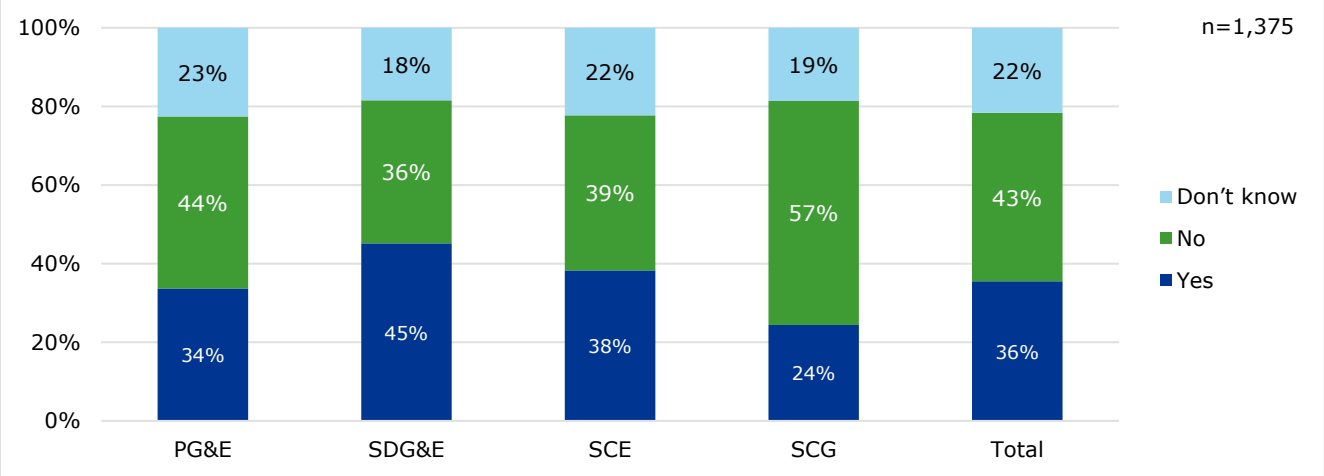
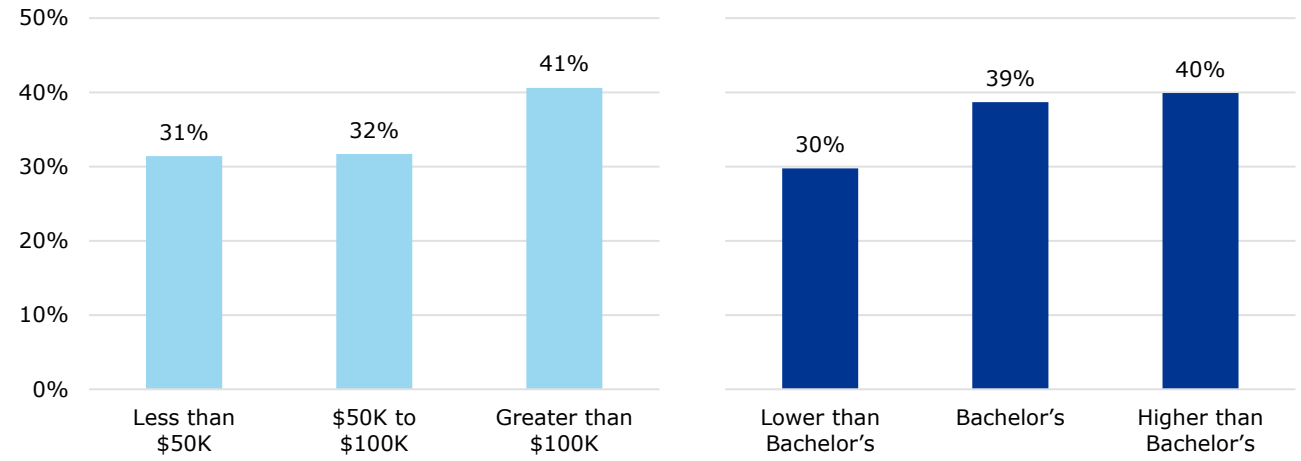


Figure 4-32 shows that participation in a PA energy-efficiency program increased with income[31] and education.[32]

[31] Difference between Less than $50K and Greater than $100K is statistically significant at the 90% confidence level.

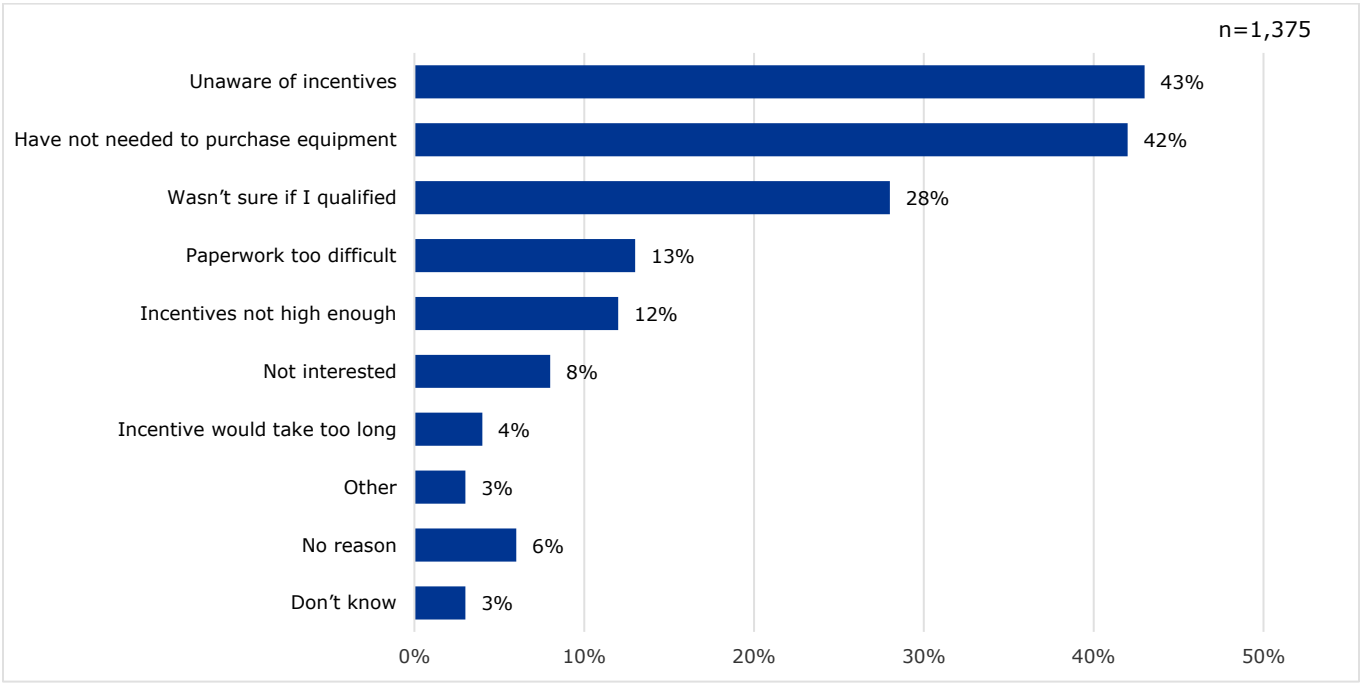
[32] Difference between Lower than bachelor's and Higher than bachelor's is statistically significant at the 90% confidence level.

Figure 4-32. Participation in PA energy-efficiency programs by income and education



The most common reasons non-participants gave for not having participated in any PA energy-efficiency programs were being unaware of the incentives (43%) and not having needed to purchase any rebated equipment (42%) as illustrated in Figure 4-33. Additionally, over one-quarter (28%) of non-participants said they were not sure they qualified.

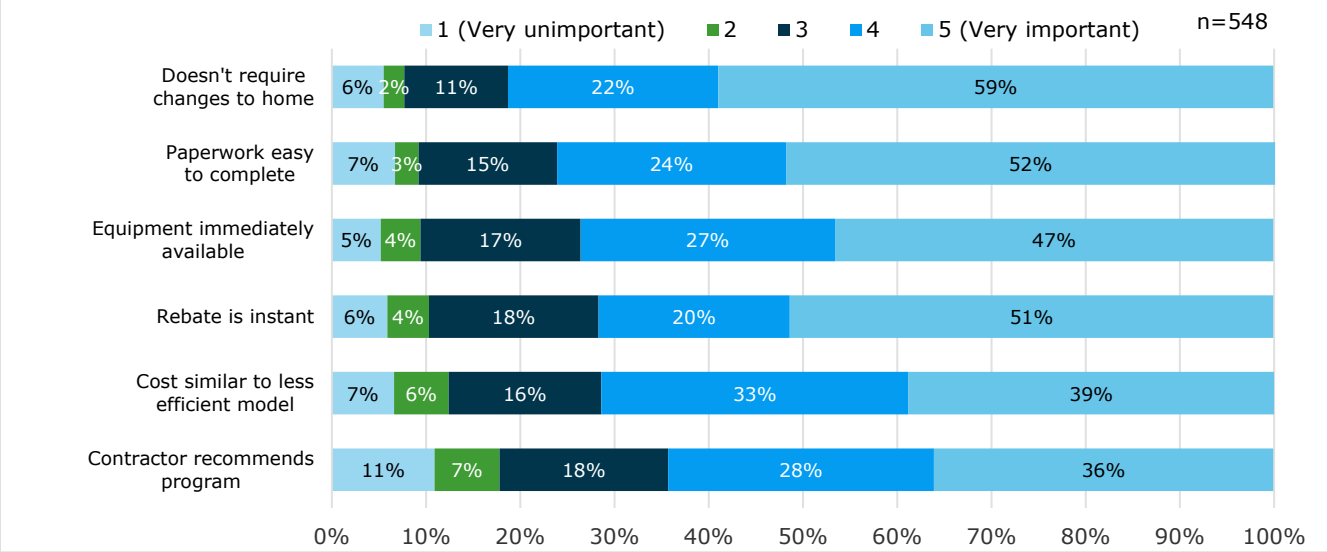
Figure 4-33. Reasons for not participating in PA energy-efficiency programs



Our team asked non-participants to rate various factors on a scale of 1 to 5 where 1 was 'very unimportant' and 5 was 'very important' to their decision to claim a rebate for energy saving equipment. The most important factor to non-participants was that the energy efficient equipment did not require any changes to the home (e.g., having to install a new electrical panel): 81% of non-participants rated this factor a 4 or 5 (Figure 4-34). The next most important factor pertained to convenience, and included the ease of paperwork (76%), immediate

availability of equipment (74%), and an instant rebate (72%). Seventy-one percent of non-participants rated the cost of the equipment being similar to a less efficient model a 4 or 5. While contractor recommendation of the program was the least important factor to non-participants, only two-thirds (64%) rated it a 4 or 5.

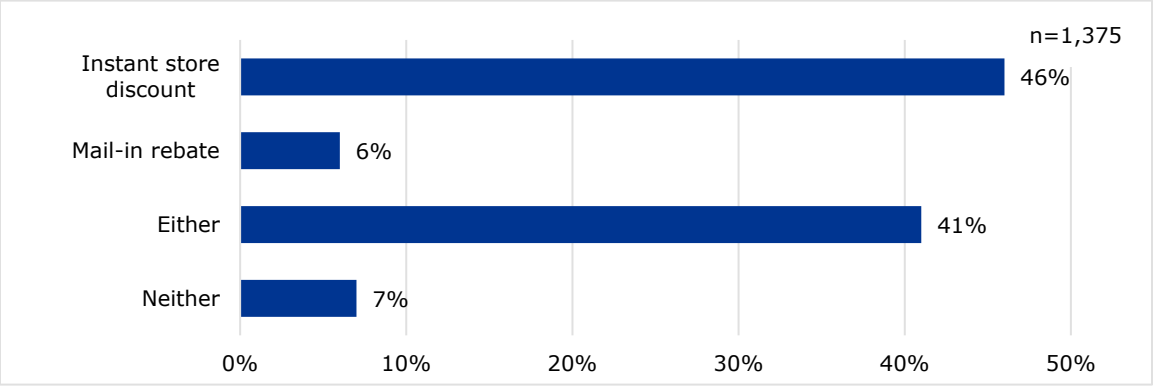
Figure 4-34. Importance of factors on decision to claim a rebate for energy saving equipment



Given that 81% of all customers indicate that not requiring changes to their home to install rebated energy-saving equipment would be a key factor in their choice of equipment, programs seeking to boost adoption of water heating equipment such as heat pump water heaters that typically require changes including wiring, pulling an electrical permit, potential panel upgrades, etc., will encounter barriers even when accompanied by an incentive. Additional support by way of contractor training and trade ally programs that can deliver one-stop/integrated solutions may be necessary to overcome these barriers.

Our team asked non-participants what form of incentive they would prefer for a high-efficiency water heater. Almost one-half (46%) preferred an instant discount, while about two-fifths (41%) said either an instant discount or mail-in rebate was fine (Figure 4-35).

Figure 4-35. Preferred form of incentive



Customers signal a slight preference for the instant store discount, which reduces their transaction burden, compared to the mail-in rebate. While program tracking data captures information on the retail channels through which the rebated product is sold, purchaser (end user or contractor) information is not captured. Programs

should explore ways to capture purchaser (end user or contractor, as applicable) contact information at the point-of-sale to enable improved measurement of program influence.

4.4.7 Water heater purchase process

Our team asked non-participants where they would go to get information if they were in the market to buy a new water heater. Respondents were permitted to provide multiple responses ; the average number of sources non-participants indicated they would consult was 2.5. Figure 4-36 shows that the most frequently mentioned source of information was an online resource other than the PA website or ENERGYSTAR.gov (52%). Plumber/contractor recommendations were a close second (50%), followed by PA website (41%), and ENERGYSTAR.gov (37%).

Figure 4-36. Sources of information on water heaters

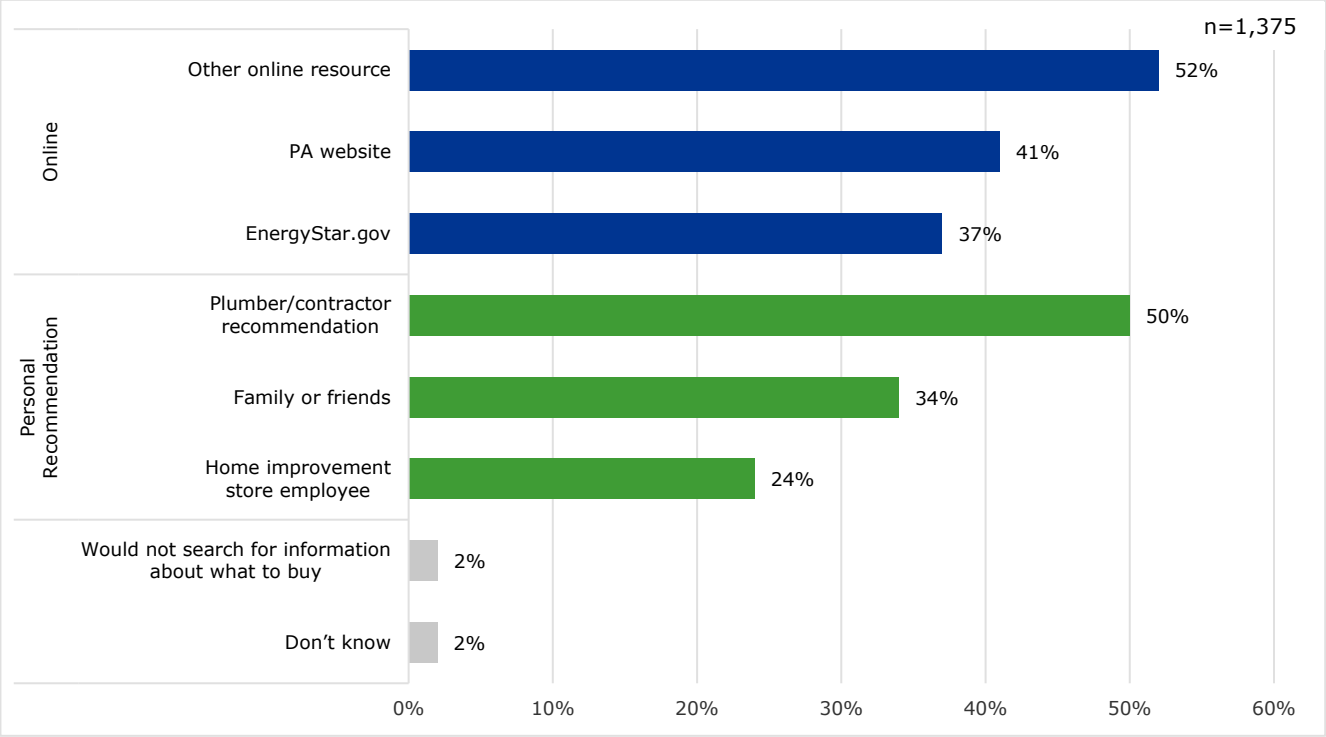


Figure 4-37 displays the percent of non-participants who said they would go online only for information (24%), seek personal recommendations only (21%), or both go online and seek personal recommendations (55%) if they were in the market to buy a new water heater. The acceleration of online shopping and e-commerce trends have an influence on how customers research and shop for energy-related products and services. Almost four-fifths (79%) of non-participants said they would go online for information, underscoring the need for a strong digital marketing component for water heater programs.

Figure 4-37. Types of sources of information on water heaters: online versus personal recommendation

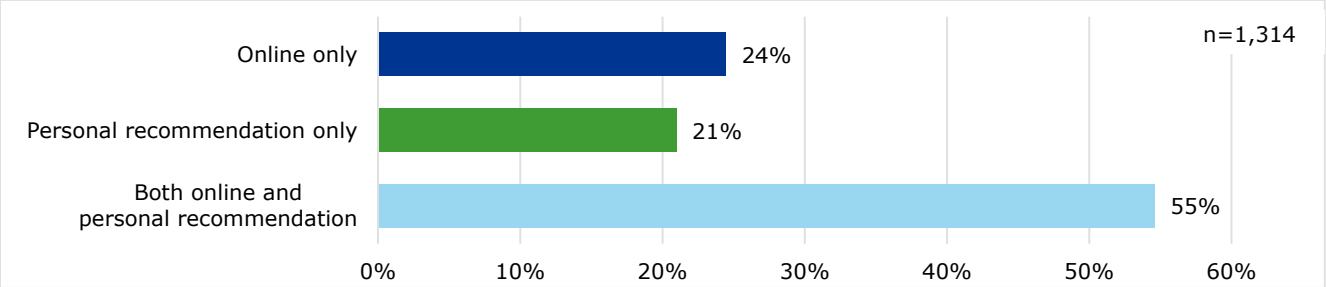


Figure 4-38 displays the top four sources of information on water heaters by PA. SDG&E and SCG customers were more likely to say they would go to a PA website (48% and 53%, respectively) than PG&E and SCE customers (41% and 31%, respectively). Additionally, SCE customers were less likely to say they would go to ENERGYSTAR.gov (29%) than PG&E (38%) and SCG (45%) customers. These differences were statistically significant.[33]

Figure 4-38. Top four sources of information on water heaters by PA

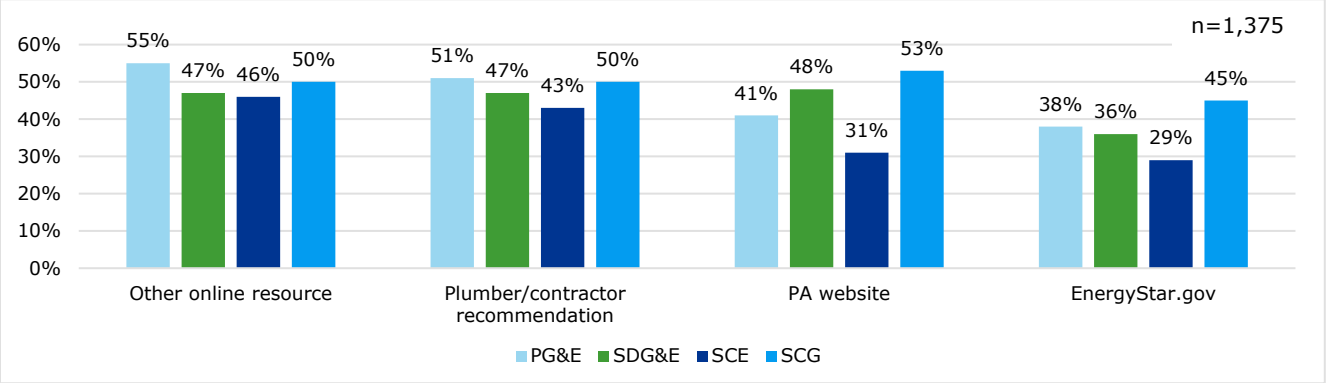


Figure 4-39 and Figure 4-40 display the top four sources of information on water heaters by income and education. The likelihood of a non-participant to consult another online resource or a plumber/contractor recommendation increased as income[34] and level of education increased.[35] The likelihood of non-participants to consult a PA website or ENERGYSTAR.gov increased with education, but not income.

[33] Statistical significance test results reported at 90% level of confidence and 10% level of significance.

[34] Difference between Less than $50K and Greater than $100K is statistically significant at the 90% confidence level.

[35] Difference between Lower than bachelor's and Higher than Bachelor's is statistically significant at the 90% confidence level.

Figure 4-39. Top four sources of information on water heaters by income

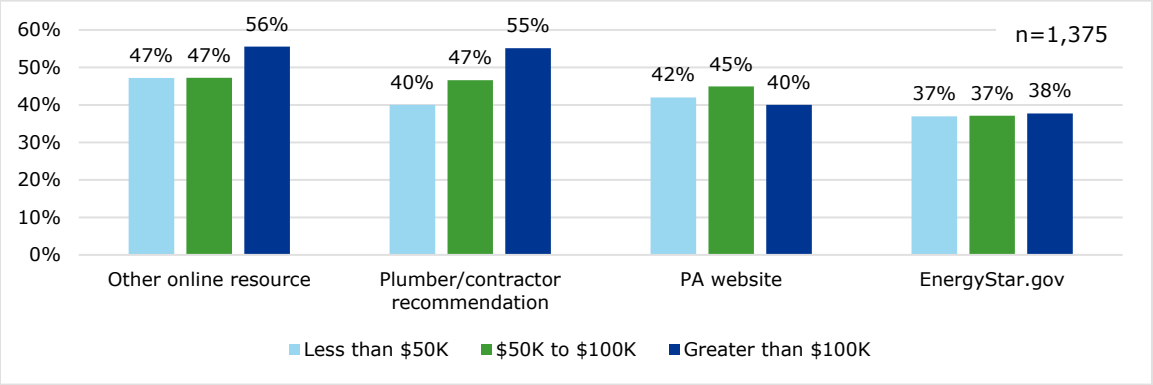
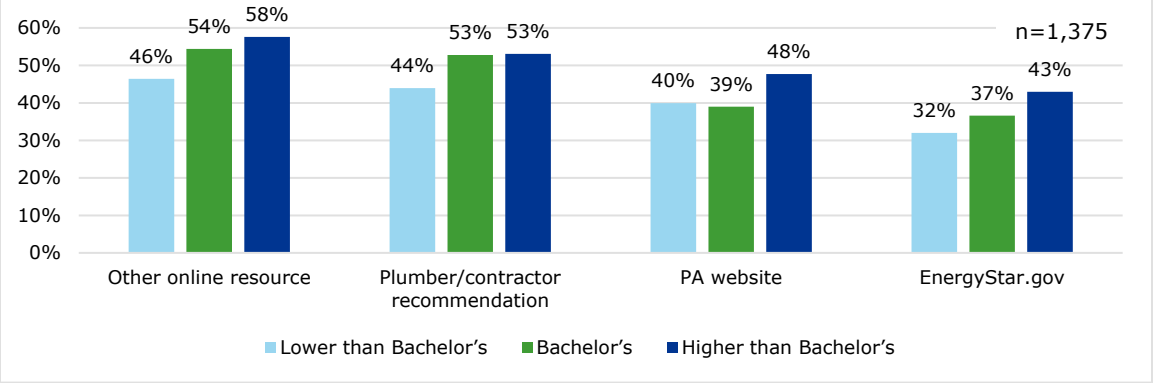


Figure 4-40. Top four sources of information on water heaters by education



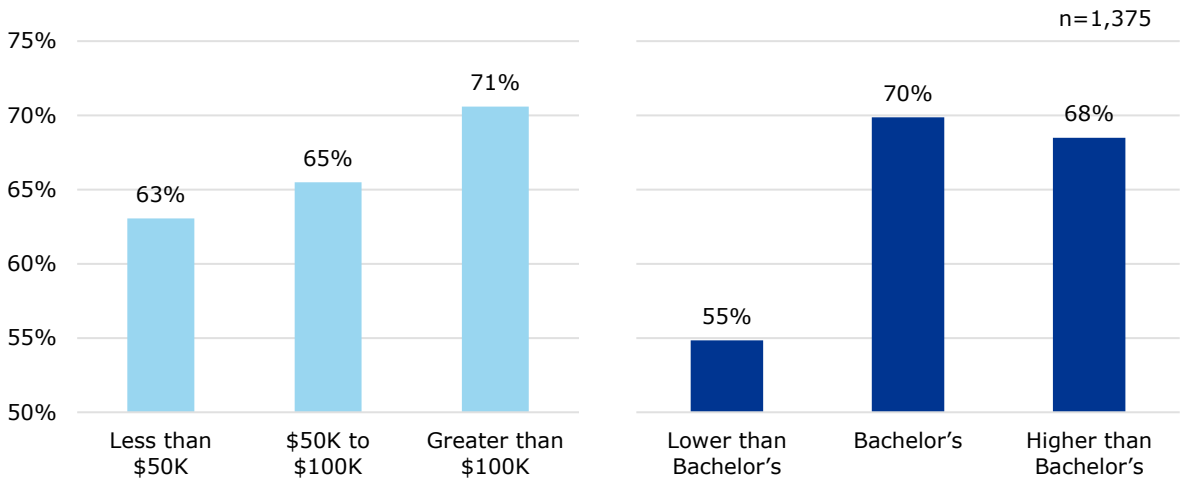
4.4.8 Demand response

We asked non-participants to indicate their willingness to participate in a water heater demand response program. As discussed previously in section 4.3.10, nearly two-thirds (64%) of non-participants were interested in such a program.Figure 4-41 shows that interest in a water heater demand response program increased with income[36] and education.[37]

[36] Difference between Less than $50K and Greater than $100K is statistically significant at the 90% confidence level.

[37] Difference between Lower than Bachelor's and Higher than Bachelor's is statistically significant at the 90% confidence level.

Figure 4-41. Interest in water heater demand response program by income and education



Per the 2019 ACS, almost half (45%) of all Californians aged 25 years and over have educational attainment levels less than a bachelor's degree. The relatively lower interest in demand response among these large customer segments suggests additional education and outreach on the benefits of demand response for the household and the grid may be needed if greater participation in demand response is desired.

4.4.9 Hot water use profiles by PA

Table 4-14 displays characteristics of non-participants that impact hot water usage and water heater purchases by PA. Differences between PAs that were statistically significant at the 90% confidence level are noted.

As shown in Table 4-14, compared to the other PAs, PG&E customers tended to have more conventional storage water heaters, more water heaters over 10 years old, more faucet aerators, and more awareness of heat pump and solar water heaters. Reducing carbon emissions and non-energy benefits were more important to PG&E customers in purchase decisions, while operating costs were less important.

SDG&E customers also tended to have more conventional storage water heaters, more aerators, and higher awareness of heat pump and solar water heaters. In addition, SDG&E customers took fewer showers and baths per household, had higher awareness of water heater temperature settings, and were more likely to have participated in energy-efficiency programs.

SCE and SCG customers were less likely to have conventional storage water heaters or faucet aerators and were less likely to have heard of heat pump water heaters than PG&E and SDG&E customers. SCG customers tended to have fewer bathrooms, less hot water pipe insulation, fewer dishwashers, and were less likely to wash their clothes in hot/warm water. Additionally, SCG customers were more likely to identify operating cost and purchase price as barriers to switching from gas to electric water heaters, and more likely to consider utility rebates/discounts in purchase decisions. Reducing carbon emissions and non-energy benefits were relatively important to SCG customers compared to other PAs, but not nearly as important as the cost factors. Finally, SCG customers were less likely to have participated in energy-efficiency programs.

Table 4-14. Non-participant hot water usage profile by PA

Characteristics	PG&E [a] (n=924)[38]	SDG&E [b] (n=215)	SCE [c] (n=157)	SCG [d] (n=79)	Total (n=1,375)
Household characteristics					
Homes with conventional storage water heater	82%[c]	81%[c]	73%[a,b]	74%	82%
Homes with gas water heater	91%	92%	90%	91%	91%
Homes with water heater over 10 years old	29%[b,c,d]	18%[a]	18%[a]	17%[a]	25%
Homes with two or more bathrooms	91%	94%	94%	85%[b,c]	92%
Homes with seven or more faucets	21%	24%	21%	18%	21%
Average number of bathrooms	2.5	2.6[d]	2.6[d]	2.4[b,c]	2.5
Average number of faucets	5.1	5.0	4.9	4.7	5.0
Homes with hot water pipes insulated	20%[d]	23%[d]	21%[d]	11%[a,b,c]	20%
Consumer behavior					
Aware of solar water heaters	51%[c]	51%[c]	35%[a,b]	45%	48%
Aware of heat pump water heaters	31%[c,d]	29%[c,d]	18%[a,b]	17%[a,b]	28%
Aware of condensing gas water heaters	12%[c]	13%	8%[a]	10%	11%
Have participated in energy-efficiency programs	34%[b,d]	45%[a,d]	38%[d]	24%[a,b,c]	36%
Utility rebate/discounts influence purchase decisions	64%[b,d]	56%[a,d]	62%[d]	75%[a,b,c]	63%
Carbon emissions influence purchase decisions	40%[b,c]	31%[a]	28%[a,c]	39%[c]	37%
Non-energy benefits influence purchase decisions	23%[b,c]	14%[a,d]	17%[a]	23%[b]	21%
Operating cost is a barrier to switching to electric	44%[b,d]	52%[a]	51%	61%[a]	47%
Purchase price is a barrier to switching to electric	31%[d]	33%[d]	35%[d]	47%[a,b,c]	33%
Would consider early replacement	57%[b,c]	47%[a]	46%[a]	56%	54%
Would purchase efficient water heater with no incentive	17%	13%	13%	19%	16%
Hot water use behavior					
1 to 3 showers per day	80%[b]	86%[a]	82%	79%	81%
4 or more showers per day	15%	12%	16%	17%	15%
Average number of showers per day	2.5[b]	2.3[a]	2.5	2.5	2.5
Baths per day – 1 or more	25% [b]	19%[a,c]	31%[b,d]	20%[c]	25%
Average number of baths per day	0.7[b]	0.5[a,c]	0.8[b]	0.5	0.7
Hot water use settings and features					
Aware of water heater temperature setting	35%[b,c]	42%[a,c]	27%[a,b]	34%	35%
Average temperature setting (°F)	122	122	119	119	122
Low-flow showerheads for some or all showers	83%[c]	81%	77%[a]	83%	81%
Water saving aerators for some or all faucets	73%[c,d]	75%[c,d]	65%[a,b]	63%[a,b]	72%
Clothes washer loads per week in hot/warm – None	17%[c]	20%[c]	10%[a,b,d]	24%[c]	17%
Clothes washer loads per week in hot/warm – 1 to 3	44%	38%	43%	39%	42%
Clothes washer loads per week in hot/warm – 4 or more	39%[c]	42%	47%[a]	38%	40%
Percent clothes washer loads with hot/warm water	58%[d]	58%[d]	62%[d]	47%[a,b,c]	58%
Have a dishwasher	90%[d]	88%[d]	86%	79%[a,b]	88%
Average number of dishwasher loads per week	2.9[c]	2.9	2.5[a]	2.5	2.8

a Statistically different from PG&E at the 90% confidence level.
b Statistically different from SDG&E at the 90% confidence level.
c Statistically different from SCE at the 90% confidence level.
d Statistically different from SCG at the 90% confidence level.

[38] The comparison made in the above are between PG&E, SDG&E, SCE, and SCG. The four groups in the table are denoted by the letters a, b, c, and d by order of appearance from left to right. Superscripted letters indicate that statistic displayed in the cell is significantly different from the corresponding group denoted by superscript.

5 CONCLUSIONS AND RECOMMENDATIONS

The findings from this evaluation and resulting recommendations and implications are summarized in Table 5-1.

Table 5-1. Key findings and Recommendations

Key findings	Recommendations & Implications
1. The single-family market is moving towards tankless systems, but fuel substitution is uncommon.	As fuel switching and electrification of water heating ramps up pursuant to PY2021 Decision 19-08-009, we recommend:
	• gross impact evaluation that factors in the mix of baseline technologies for each program technology.
	• future research using customer surveys to monitor the fuel-conversion trend from gas to electric heat pump water heaters.
2. Almost three-fourths of program water heater installations in PY2019 were natural gas tankless water heaters.	Program must consider the increased measure life of tankless gas water heaters that will reduce and delay the opportunities for fuel substitution initiated due to equipment failure.

Key findings	Recommendations & Implications
	It may be necessary to consider replacing recent tankless gas installations before they reach the end of their effective useful life, given that these systems are expected to last until 2040 and this is by when the state aims to be carbon neutral.
3. Over half the participants who installed heat pumps were unaware of the technology prior to starting their project (52%). Nearly three-fourth (72%) of non-participants were unaware of heat pump water heaters, and the primary reason for not wanting to install heat pump water heaters was unfamiliarity with the technology (48%).	To overcome barriers to electrification, programs should focus on educating customers on efficient electric water-heater technologies and their operating costs.
4. Nearly one-fifth (19%) of heat pump adopters indicated that they had to undertake an electrical panel upgrade. The cost to replace an electrical panel averages $1,138, with a typical range of $498 and $1,781.	We recommend revisiting the cost-benefit analysis for this measure in order to account for these customer barriers and potential additional program costs to overcome the same fully.
	They should address often-hidden costs such as panel upgrades with additional education and incentives to customers and the contractors that serve them.
5. Four-fifths (80%) of non-participants' water heaters were conventional storage, the least efficient type of water heater. One-quarter (25%) of non-participants' water heaters were more than 10 years old and would soon reach the end of their useful life.	There is ample opportunity to achieve energy savings by encouraging customers to replace conventional storage water heaters with more efficient types.
6. Results indicate that increasing incentives could encourage mass market adoption of high efficiency water heaters in single-family homes.	Programs should consider sliding scale incentives based on income eligibility to ensure that program influence is high and free-ridership is minimized.
7. A majority of non-participants indicate they search on the web or go to PA websites for information on new water heaters.	Optimize PA websites to increase visibility of efficient water-heater technologies and available rebates in search engine results.
Fifty percent of non-participants indicated that contractor recommendations are a key source of information when considering	Programs should offer both instant and mail-in rebate options and ensure that these appear in ENERGYSTAR.gov's rebate finder.

Key findings	Recommendations & Implications
purchase of a new water heater and 20% indicated personal recommendations were their only source of information when considering purchase of a new water heater.	Programs should also leverage contractors as a key channel to market efficient water heaters to customers. The contractor channel is especially important to the segment of market that indicated personal recommendations were their only source of information when considering purchase of a new water heater.
8. Approximately one-fourth of non-participants indicate that they would be motivated to replace their water heaters based on recommendations from friends and family or contractors.	We recommend use of customer testimonials and strengthening trade ally networks to deliver PA programs that encourage adoption of energy efficient water heaters.
9. The most important factor in deciding to claim a rebate for energy efficient equipment (cited by 81% of non-participants) was that the equipment did not require any changes to the home. Heat pump water heaters require up to seven feet of vertical clearance, 1,000 cubic feet of uncooled space, and a nearby drain to discharge the condensate. The most common reason why non-participants did not want to install solar water heaters was not having solar panels and not planning to install them (38% of non-participants).	Consider customizing marketing for different water heater technologies.
	Heat Pump Water Heaters: Describe the easiest way to accommodate the unique requirements of a heat pump water heater.
	Solar PV: Target customers who already have solar PV panels installed.
	Tankless and Condensing Gas: Emphasize that these technologies do not require any changes to the home in marketing messaging.

6 APPENDICES

6.1 Appendix A: Gross and net lifecycle savings

The gross and net lifecycle savings ATR tables are in the attached PDF.

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

The per unit (quantity) gross and net energy savings ATR tables are in the attached PDF.

6.3 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 Water Heating Measures - Program Year 2019	Peter Franzese

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
1	Multiple programs delivering water heating measures	The single-family market is moving towards tankless systems, but fuel substitution is uncommon.	Section 4.3	As fuel switching and electrification of water heating ramps up pursuant to PY2021 Decision 19-08-009, we recommend: • gross impact evaluation that factors in the mix of baseline technologies for each program technology. • future research using customer surveys to monitor the fuel-conversion trend from gas to electric heat pump water heaters.	CPUC, All PAs	Statewide WP, CPUC water heating calculator update
2	Multiple programs delivering water heating measures	Almost three-fourths of program water heater installations in PY2019 were natural gas tankless water heaters.	Section 4.3	Program must consider the increased measure life of tankless gas water heaters that will reduce and delay the opportunities for fuel substitution initiated due to equipment failure. It may be necessary to consider replacing recent tankless gas installations before they reach the end of their effective useful life, given that these systems are expected to last until 2040 and this is by when the state aims to be carbon neutral.	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
3	Multiple programs delivering water heating measures	Over half the participants who installed heat pumps were unaware of the technology prior to starting their project (52%). Nearly three-fourth (72%) of non-participants were unaware of heat pump water heaters, and the primary reason for not wanting to install heat pump water heaters was unfamiliarity with the technology (48%).	Section 4.3	To overcome barriers to electrification, programs should focus on educating customers on efficient electric water-heater technologies and their operating costs.	CPUC ED, All PAs	N/A (Program design consideration)
4	Multiple programs delivering water heating measures	Nearly one-fifth (19%) of heat pump adopters indicated that they had to undertake an electrical panel upgrade. The cost to replace an electrical panel averages $1,138, with a typical range of $498 and $1,781.	Section 4.3	We recommend revisiting the cost-benefit analysis for this measure in order to account for these customer barriers and potential additional program costs to overcome the same fully. They should address often-hidden costs such as panel upgrades with additional education and incentives to customers and the contractors that serve them.	CPUC ED, All PAs	Statewide WP, Program design consideration
5	Multiple programs delivering water heating measures	Four-fifths (80%) of non-participants' water heaters were conventional storage, the least efficient type of water heater. One-quarter (25%) of non-participants' water heaters were more than 10 years old and would soon reach the end of their useful life.	Section 4.4	There is ample opportunity to achieve energy savings by encouraging customers to replace conventional storage water heaters with more efficient types.	CPUC ED, All PAs	N/A (Program design consideration)
6	Multiple programs delivering water heating measures	Results indicate that increasing incentives could encourage mass market adoption of high efficiency water heaters in single-family homes.	Section 4.4	Programs should consider sliding scale incentives based on income eligibility to ensure that program influence is high and free-ridership is minimized.	CPUC ED, 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
6	Multiple programs delivering water heating measures	A majority of non-participants indicate they search on the web or go to PA websites for information on new water heaters.	Section 4.4	Optimize PA websites to increase visibility of efficient water-heater technologies and available rebates in search engine results. Programs should offer both instant and mail-in rebate options and ensure that these appear in ENERGYSTAR.gov's rebate finder.	All PAs	N/A (Program design consideration)
7	Multiple programs delivering water heating measures	Fifty percent of non-participants indicated that contractor recommendations are a key source of information when considering purchase of a new water heater and 20% indicated personal recommendations were their only source of information when considering purchase of a new water heater.	Section 4.4	Programs should leverage contractors as a key channel to market efficient water heaters to customers given that 50% indicated that contractor recommendations are a key source of information when considering purchase of a new water heater. The contractor channel is especially important for the 20% of the market that indicated personal recommendations were their only source of information when considering purchase of a new water heater. We recommend use of customer testimonials and strengthening trade ally networks to deliver PA programs that encourage adoption of energy efficient water heaters.	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
8	Multiple programs delivering water heating measures	The most important factor in deciding to claim a rebate for energy efficient equipment (cited by 81% of non-participants) was that the equipment did not require any changes to the home. Heat pump water heaters require up to seven feet of vertical clearance, 1,000 cubic feet of uncooled space, and a nearby drain to discharge the condensate. The most common reason why non-participants did not want to install solar water heaters was not having solar panels and not planning to install them (38% of non-participants).	Section 4.4	Consider customizing marketing for different water heater technologies. Heat Pump Water Heaters: Describe the easiest way to accommodate the unique requirements of a heat pump water heater. Solar PV: Target customers who already have solar PV panels installed. Tankless and Condensing Gas: Emphasize that these technologies do not require any changes to the home in marketing messaging.	CPUC ED, All PAs	Statewide WP, Program design consideration

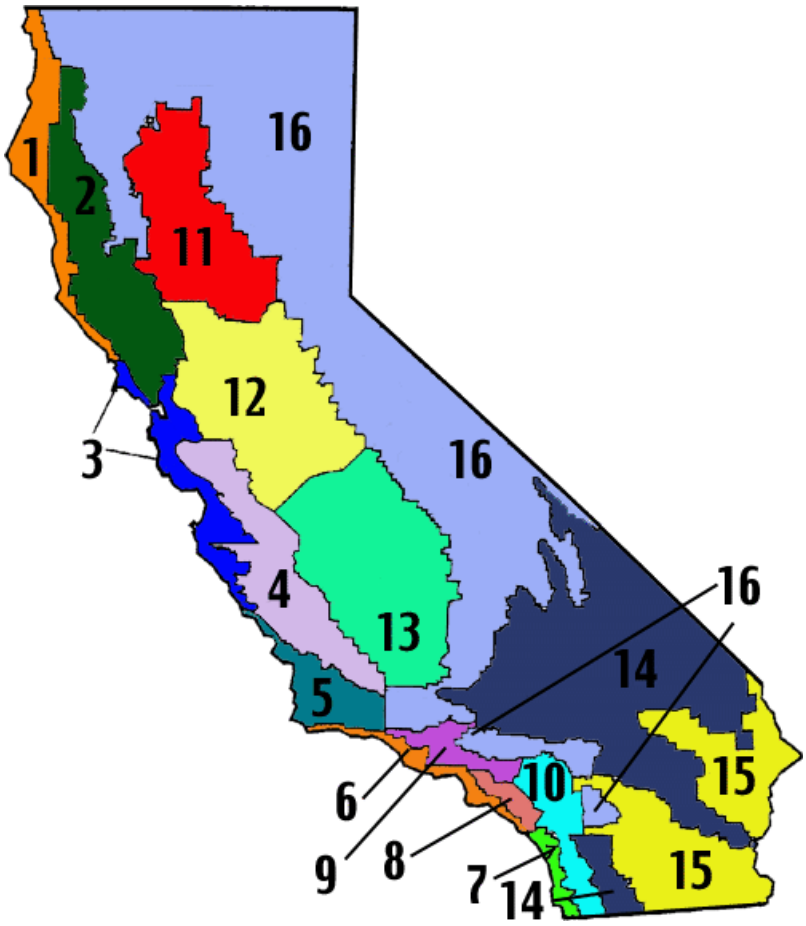
6.4 Appendix D: Climate zone

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 6-1). Efficiency standards developed and adopted for various building and measure conditions reflect the varying effect of the CEC CZs. For the purpose of developing survey weightings, we have grouped the 16 CEC CZs into three climate regions: Coastal, inland, and desert. Table 6-1 provides these groupings along with the percent of electric and gas savings climate by climate region.

Table 6-1. Climate zone groupings and percent claims by climate region

Climate region	CEC climate zone	Percent program participant				
		MCE	PG&E	SCE	SCG	SDG&E
Coastal/Mild	1,2,3,4,5,6,7,16	100%	57%	7%	21%	65%
Inland	8,9,10,11,12,13	0%	43%	67%	76%	35%
Desert	14,15	0%	0%	27%	3%	0%

Figure 6-1. California CEC climate zones



6.5 Appendix E: NTGR survey scoring

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

Timing and efficiency are directly applicable to all water heater program participants. The applicability of the quantity dimension varied by the type of survey respondent. The various PA-delivered programs that provided water heaters to residential customers gave rebates for one water heater installation per household. Thus, occupant survey respondents could only receive a single water heater and the quantity dimension is not applicable. However, survey respondents who are multifamily property managers[39] could be responsible for multiple homes and could have decided to install the water heating equipment in more or fewer units. Thus, the quantity dimension is applicable to these survey respondents.

Table 6-2 shows how each free-ridership dimension was assessed in relation to the survey respondent type, question, and answer. In instances where the survey respondent did not know the answer, the free-ridership score for that dimension equals the average of the other respondents. For example, if a respondent did not know when they would have purchased the water heater if the rebate program had not been offered, the respondent's free-ridership score for the timing dimension equals the average of the other respondents' free-ridership score for the timing dimension.

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

Table 6-2. Free-ridership elements

Survey Respondents	Free-ridership Dimension	Question Wording	Answer	Free-ridership Score
Participants (occupants)	Timing – (FR_t)	If [PA] hadn't offered a rebate program in 2019, when would you have purchased the water heater?	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 [PA] hadn't offered a rebate program in 2019, when would you have purchased the water heater?	At the same time or sooner	1
			1 to 48 months later	(48 - # of months)/48
			More than 48 months later	0
			Never	0
			Don't know	Average of non-Don't know answers
Participants (occupants) Property managers	Efficiency (FR_e)	(Type) Water heaters come in a variety of fuel types and technologies. You installed a [equipment type] through the program. Without the rebate would you have purchased the same type, a different type, or would not have purchased one at all? (Efficiency) If the [PA] program hadn't offered a [amount] rebate in 2019, would you have purchased the same higher efficiency water heater at your own expense?	Same type *and* efficiency	1
			Different technology, different fuel type, and/or different efficiency	1 if consumption <= to installed technology
				0 if consumption >= baseline
				0.5 if consumption between baseline and installed technology
			Would not have purchased a water heater	0
			Don't know	Average of non-Don't know answers
Property Managers	Quantity (FR_q) Property Manager survey	In the absence of the program, how many water heaters would you have purchased and installed at this property?	The same number or more	100
			Fewer	(#installed - #fewer)/ (#installed)
			None	0
			Don't know	Average of non-Don't know answers

For the efficiency dimension of free-ridership, if a respondent would have purchased a different technology, fuel type, or efficiency without the rebate, free-ridership is assessed based on the consumption of the water heater type and efficiency that the respondent would have purchased without the rebate relative to the consumption of the water heater rebated and its baseline technology. The baseline technology is assumed to be a standard efficiency conventional gas storage tank water heater, except when the rebated water heater was an electric storage tank water heater. In these instances, the baseline technology is assumed to be a standard efficiency conventional electric storage tank water heater. Table 6-3 shows how free-ridership was assessed for each permutation of survey responses (the other, theoretically possible permutations are left off the table for brevity).

Table 6-3. Free-ridership efficiency elements – different technology, fuel type, or efficiency

Purchased	Would Have Purchased		Free-ridership Score
	Type	Efficiency	
Conventional storage tank fueled by gas	Conventional storage tank fueled by gas	Would have purchased a minimum standard efficiency water heater	0
		Would have purchased the same high efficiency water heater	1
	Heat pump (all-electric)	Would have purchased the same high efficiency water heater	1
	Tankless fueled by gas	Would have purchased a minimum standard efficiency water heater	0.5
		Would have purchased the same high efficiency water heater	1
Heat pump (all-electric)	Condensing water heater	Would have purchased the same high efficiency water heater	0.5
	Conventional storage tank fueled by electricity	Would have purchased a minimum standard efficiency water heater	0
	Heat pump (all-electric)	Would have purchased the same high efficiency water heater	1
Tankless fueled by gas	Conventional storage tank fueled by gas	Would have purchased a minimum standard efficiency water heater	0
		Would have purchased the same high efficiency water heater	0.5
	Heat pump (all-electric)	Would have purchased the same high efficiency water heater	0.5
	Tankless fueled by electricity	Would have purchased the same high efficiency water heater	0.5
	Tankless fueled by gas	Would have purchased a minimum standard efficiency water heater	0.5
		Would have purchased the same high efficiency water heater	1

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 participants based on the occupant survey

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

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

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

Equation 3: 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) and property manager surveys are summarized in Section 4.3.7. 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.

6.6 Appendix F: Sample weights

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

Participant survey – sample weights. The team applied respondent-level sample weights, in order to balance the participant survey sample to the population proportions by fuel, climate zone group, and consumption level combinations. The team applied measure-level sample weights for the net-to-gross analysis. No trimming of respondent-level occupant weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.55, 1.69, and 3.07 respectively (Table 6-4). Minimum cell size to which weights were applied was 14. This indicates a balanced survey sample requiring minor corrections for over and under representation thus reducing the design effect on the data and any potential inflation of standard errors for estimated statistics.

Table 6-4. Participant (occupant) survey sample weights

Climate zone group	Consumption tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight = %N/%n
Coastal	missing	202	42	3%	4%	0.68
Coastal	1	487	102	7%	10%	0.67
Coastal	2	486	113	7%	11%	0.61
Coastal	3	488	64	7%	6%	1.07
Desert	1	94	19	1%	2%	0.70
Desert	2	70	14	1%	1%	0.70
Desert	3	70	18	1%	2%	0.55
Inland	missing	1043	87	14%	8%	1.69
Inland	1	1516	213	20%	20%	1.00
Inland	2	1508	241	20%	23%	0.88
Inland	3	1510	139	20%	13%	1.53

No trimming of respondent-level property manager weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.19, 2.07, and 10.80 respectively (Table 6-5). Minimum cell size to which weights were applied was 3.

Table 6-5. Participant (property manager) survey sample weights

Climate zone group	Consumption tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight = %N/%n
coastal	1	41	16	7%	14%	0.47
coastal	2	24	23	4%	20%	0.19
coastal	3	38	9	6%	8%	0.78
inland	missing	27	3	4%	3%	1.65
inland	1	169	15	27%	13%	2.07
inland	2	162	24	26%	21%	1.24
inland	3	160	24	26%	21%	1.22

Measure-level weights applied for the net-to-gross ratio analysis are shown in Table 6-6.

Table 6-6. Participant survey measure-level sample weights

Survey	PA	Measure	CZ cate-gory	Consump-tion tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight (%N/ %n)
Occupant	PG&E	Heat Pump Water Heater	Coastal	missing	30	15	0.004	0.013	0.31
Occupant	PG&E	Heat Pump Water Heater	Coastal	1	22	10	0.003	0.009	0.34
Occupant	PG&E	Heat Pump Water Heater	Coastal	2	26	10	0.003	0.009	0.40
Occupant	PG&E	Heat Pump Water Heater	Coastal	3	11	6	0.001	0.005	0.28
Occupant	PG&E	Heat Pump Water Heater	Inland	missing	42	14	0.006	0.012	0.46
Occupant	PG&E	Heat Pump Water Heater	Inland	1	8	2	0.001	0.002	0.61
Occupant	PG&E	Heat Pump Water Heater	Inland	2	14	6	0.002	0.005	0.36
Occupant	PG&E	Heat Pump Water Heater	Inland	3	7	2	0.001	0.002	0.54
Occupant	SCE	Heat Pump Water Heater	Desert	missing	13	2	0.002	0.002	1.00

Survey	PA	Measure	CZ cate-gory	Consump-tion tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight (%N/ %n)
Occupant	SCG	Natural Gas Storage Water Heater	Coastal	missing	14	2	0.002	0.002	1.07
Occupant	SCG	Natural Gas Storage Water Heater	Coastal	1	82	21	0.011	0.018	0.60
Occupant	SCG	Natural Gas Storage Water Heater	Coastal	2	85	21	0.011	0.018	0.62
Occupant	SCG	Natural Gas Storage Water Heater	Coastal	3	46	7	0.006	0.006	1.01
Occupant	SCG	Natural Gas Storage Water Heater	Desert	1	22	3	0.003	0.003	1.12
Occupant	SCG	Natural Gas Storage Water Heater	Desert	2	33	6	0.004	0.005	0.84
Occupant	SCG	Natural Gas Storage Water Heater	Desert	3	24	5	0.003	0.004	0.73
Occupant	SCG	Natural Gas Storage Water Heater	Inland	missing	37	5	0.005	0.004	1.13
Occupant	SCG	Natural Gas Storage Water Heater	Inland	1	303	44	0.041	0.038	1.05
Occupant	SCG	Natural Gas Storage Water Heater	Inland	2	434	56	0.058	0.049	1.19
Occupant	SCG	Natural Gas Storage Water Heater	Inland	3	142	16	0.019	0.014	1.36
Occupant	SCG	Natural Gas Tankless Water Heater	Coastal	missing	134	23	0.018	0.020	0.89

Survey	PA	Measure	CZ cate-gory	Consump-tion tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight (%N/ %n)
Occupant	SCG	Natural Gas Tankless Water Heater	Coastal	1	341	60	0.046	0.052	0.87
Occupant	SCG	Natural Gas Tankless Water Heater	Coastal	2	361	76	0.048	0.066	0.73
Occupant	SCG	Natural Gas Tankless Water Heater	Coastal	3	286	51	0.038	0.045	0.86
Occupant	SCG	Natural Gas Tankless Water Heater	Desert	1	48	13	0.006	0.011	0.57
Occupant	SCG	Natural Gas Tankless Water Heater	Desert	2	39	8	0.005	0.007	0.75
Occupant	SCG	Natural Gas Tankless Water Heater	Desert	3	46	13	0.006	0.011	0.54
Occupant	SCG	Natural Gas Tankless Water Heater	Inland	missing	932	61	0.125	0.053	2.34
Occupant	SCG	Natural Gas Tankless Water Heater	Inland	1	1165	163	0.156	0.142	1.09
Occupant	SCG	Natural Gas Tankless Water Heater	Inland	2	1055	171	0.141	0.149	0.94
Occupant	SCG	Natural Gas Tankless Water Heater	Inland	3	837	115	0.112	0.101	1.11
Occupant	SDG&E	Heat Pump Water Heater	Coastal	1	10	5	0.001	0.004	0.31
Occupant	SDG&E	Heat Pump Water Heater	Inland	missing	13	4	0.002	0.003	0.50
Occupant	SDG&E	Natural Gas Storage Water Heater	Coastal	1	24	5	0.003	0.004	0.73

Survey	PA	Measure	CZ category	Consumption tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight (%N/%n)
Occupant	SDG&E	Natural Gas Storage Water Heater	Coastal	2	7	3	0.001	0.003	0.36
Occupant	SDG&E	Natural Gas Storage Water Heater	Coastal	3	4	2	0.001	0.002	0.31
Occupant	SDG&E	Natural Gas Storage Water Heater	Inland	2	25	3	0.003	0.003	1.28
Property Manager	SCG	Central System Natural Gas Storage Water Heater	Inland	3	25	4	0.003	0.003	0.96
Property Manager	SCG	Central System Natural Gas Tankless Water Heater	Inland	3	9	2	0.001	0.002	0.69
Property Manager	SCG	Natural Gas Tankless Water Heater	Coastal	2	17	2	0.002	0.002	1.30
Property Manager	SCG	Natural Gas Tankless Water Heater	Inland	1	13	2	0.002	0.002	1.00
Property Manager	SCG	Natural Gas Tankless Water Heater	Inland	2	16	4	0.002	0.003	0.61
Property Manager	SCG	Recirculation Pump Demand Controls	Coastal	3	69	11	0.009	0.010	0.96
Property Manager	SCG	Recirculation Pump Demand Controls	Inland	missing	32	4	0.004	0.003	1.22
Property Manager	SCG	Recirculation Pump Demand Controls	Inland	3	325	38	0.043	0.033	1.31
Property Manager	SCG	Water Heater Boiler Controllers	Coastal	3	33	29	0.004	0.025	0.17

Survey	PA	Measure	CZ category	Consumption tercile (therms)	Participant population (N)	Participant survey sample (n)	Participant population proportion (%N)	Participant survey sample proportion (%n)	Survey sample weight (%N/%n)
Property Manager	SCG	Water Heater Boiler Controllers	Coastal	3	31	5	0.004	0.004	0.95
Property Manager	SCG	Water Heater Boiler Controllers	Inland	3	100	3	0.013	0.003	5.10
Property Manager	SCG	Water Heater Boiler Controllers	Inland	3	80	11	0.011	0.010	1.11

Non-participant survey - sample weights. The team applied sample weights to balance the non-participant survey sample to the population proportions by each PA, fuel, climate zone category, and consumption-level combinations. Only twenty-two non-participant respondents were from the desert climate zone group; these respondents were grouped into other climate zone groups based on consumption tercile and geography. No trimming of weights was required with the maximum weight, minimum weight, and the ratio of the maximum to minimum sample weight at 0.65, 1.43, and 2.21 respectively (Table 6-7). This indicates a balanced survey sample requiring minor corrections for over and under representation thus reducing the design effect on the data and any potential inflation of standard errors for estimated statistics.

Table 6-7. Non-participant survey sample weights

Climate zone group	Consumption tercile (therms)	Non-Participant population (N)	Non-Participant survey sample (n)	Non-Participant population proportion (%N)	Non-Participant survey sample proportion (%n)	Survey sample weight = %N/%n
Coastal	missing	24,620	124	6%	9%	0.70
Coastal	1	52,033	128	13%	9%	1.43
Coastal	2	63,238	203	16%	15%	1.10
Coastal	3	64,958	238	17%	17%	0.96
Inland	missing	18,751	102	5%	7%	0.65
Inland	1	61,769	154	16%	11%	1.41
Inland	2	52,263	210	13%	15%	0.88
Inland	3	53,588	217	14%	16%	0.87

6.7 Appendix G: Surveys

6.7.1 Occupant surveys – Program participants and Non-participants

6.7.1.1 Program participant survey

The survey is in the attached PDF.

6.7.1.2 Non-participant survey

The survey is in the attached PDF.

6.7.2 Property manager survey

The survey is in the attached PDF.

6.8 Appendix H: Response to comments

Response ID	Commenter	Page (as shown in Word document footer)	Comment	Response
1	PGE	5	**Binary view of consumer decision-making in making major appliance purchasing decisions**: Could DNV reassess its current interpretation of the survey responses that assumes that a single factor—either equipment malfunction or program incentives—drives consumer decision making for purchase decisions for water heating system?	Section 4.3.5, Figure 4.3 presents motivators of water heater replacement for program participants and non-participants. While the motivators pertain to the impetus for the current installation for participants, the figure presents prospective motivators for non-participants. Edits made to the Executive Summary to refer to the other motivators presented later in the report.
2	PGE	5	**Potential role of social desirability bias in survey responses:** In the "Key findings and recommendations" section (page 5), the report states that "[m]ost customers state that they would have acquired the more efficient model even without the program. These findings lead directly to low program attribution with net-to-gross ratios (NTGRs) of 40% for storage, 36% for tankless, and 48% for HPWHs. Could DNV discuss the possibility that some survey respondents might reply that they would have purchased efficient equipment even in the absence of the rebate for reasons of social desirability?	Yes. It is possible that social desirability could affect the scores. However, the questions we score ask specifically about timing, efficiency, and quantity. The more precise nature of these questions hopefully reduces the social desirability biases. Furthermore, the efficiency question and the response options are worded to minimize this bias.
3	PGE	5	**Higher NTGRs for lower income customers and customers in smaller homes (<2,000 square feet):** Could DNV provide more detail about this conclusion to aid the IOUs in targeting these segments? We were unable to find more information regarding this statement elsewhere in the report.	While the evaluation found some evidence of higher program influence among customers in smaller homes and among customers in older homes acquiring heat pumps, this finding is not uniform across all technologies and relevant demographic dimensions. Edits have now been made to reflect this. Variability in program influence by key demographic segments should continue to be studied further in future evaluations.
4	PGE	27	**Measure-level NTGRs:** Could DNV please point to which of the Impact Evaluation Standard Reporting (IESR) tables these values have been applied, and how? In a case in which the DEER default NTGR is within the range estimate calculated by the relative precision as shown in this table, is the appropriate interpretation that no significant difference was found between the DEER default NTGR and the evaluated NTGR?	The reported NTGRs are applied to claims by PA and Measure Group combinations and are used to calculate first year and lifecycle net savings as summarized in IESR tables in Appendices A and B. The NTGRs shown in the IESR tables include a 5% Market Effects Benefit. While the NTGRs in DEER are based on multiple evaluations over several years that represent typical values, the NTGRs used in the PY2019 evaluation are solely based on responses gathered from PY2019 participants. If DEER ex ante is within the confidence limit, we would say no significant difference. The PY2019 evaluation applies the point estimates for NTGRs determined from this evaluation, irrespective of whether they are significantly different from DEER values or not.
5	PGE	37	**Request clarification of decision to include timing as factor in attribution, and suggestions to change program design to persuade residential customers to do early replacements of water heating systems:** 1. Could DNV please explain why the water heating program NTGR scoring algorithm penalizes the purchase of water heating measures on the basis of not having accelerated the timing of equipment replacement prior to its failing, when nine in ten customers surveyed indicate that replacement on burnout is	The scoring does not penalize for not accelerating. The algorithm assigns partial (0<=FR<=1) FR for any response within 2 years of when they replaced it. It then multiplies that partial FR by another partial FR (or two other partial FRs if quantity applies) to get total FR. Attribution is then assigned as 1 minus the total FR. By multiplying multiple fractions together, and THEN subtracting from 1, the algorithm actually gives extra credit unless the respondent would have installed at the same time as they did. In the case of no change to timing, the timing FR is equal to 1 and thus has *no effect* on the final score.

Response ID	Commenter	Page (as shown in Word document footer)	Comment	Response
			the standard practice of customers in the single family replacement water heater appliance market?	
6	PGE	37	**Request clarification of decision to include timing as factor in attribution, and suggestions to change program design to persuade residential customers to do early replacements of water heating systems:** 2. Since the attribution scoring imposes an NTGR penalty when customers do not typically replace water heating equipment that is functioning normally, could DNV suggest how the IOUs could change the program design to persuade customers to do early replacements of their water heating systems so that attribution scoring could improve?	The scoring does not penalize for not accelerating. See answer to comment #5.
7	PGE	40	**Figure 4-19:** Could DNV please change the n for this figure to reflect the accurate base, and interpret the results in the text as a percentage of total customers surveyed, because as shown it is misleading? According to Figure 4-18, only 54%, or approximately 743 respondents who answered “yes” or “maybe” to the question “would you replace a working water heater?” were presented with this question.	Figures 4-18 and 4-19 are presenting the same information with the same base; the difference is that Figure 4-19 is broken out by PA and 'yes' & 'maybe' are consolidated. We made the following edits: 1) edited the Figure 4-18 heading to match the 4-19 heading; 2) added text clarifying what Figure 4-19 shows; 3) fixed an incorrect figure cross reference that may have caused confusion.
8	PGE	43	**Figure 4-25:** Could DNV please change the n for this figure to reflect the accurate base for these two bar charts, and interpret the results in the text as a percentage of total customers surveyed, because as shown it is misleading? According to the text prior to this figure, only 17% of the 1,375 respondents answering “4” or “5” on a 1-to-5 scale of likelihood to consider heat pumps were presented with this question.	We had inserted the wrong chart here. Updated with the correct chart. Thanks for pointing this out.
9	PGE	49	**Figure 4-36:** Could DNV please provide a more nuanced interpretation of the data presented in this figure? Perhaps DNV could do some sort of cluster analysis or quick segmentation to showing how different types of people get their information. If that’s too much, perhaps these sources could be grouped categorically (e.g., online, professionals, retailers, family/friends)? As presented here, seeing that 41% “most frequently mentioned PA website” and 37% “most frequently mentioned EnergyStar.gov” and 50% “most frequently mentioned plumber/contractor recommendation” (these three alone adding up to 128%) doesn’t give PAs much actionable advice.	We have made a few edits and additions in response to this comment: 1) Grouped the responses by category: online or personal recommendation. 2) Added a new figure consolidating the responses into these groups and showing the percent who only go online, only seek personal recommendations, or do both. 3) Added in a new figure and text looking at responses by PA 4) Added in two new figures and text looking at responses by income and education. These were the only two demographic categories that had significant differences, so we have only added these two. Recommendations based on these findings are presented in the executive summary, and include ways to optimize online visibility & leveraging contractors.
10	PGE	54	**Key finding #3:** The evaluation notes that “over half the participants who installed heat humps were unaware of the technology prior to starting their project (52%).” That statistic suggests that the program led to more than half of the participants becoming aware of the measure and that	The question about awareness of the technology is not used in the scoring algorithm. The statistic in the key finding in the executive summary should have stated that 52% were aware of the technology prior to starting the project. Edits have been made.

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			awareness led to their participation in the program. That being the case, how can the NTGR be under 50%?	Even with a generous interpretation that the program is responsible for the awareness of the other 48%, that is the same number as we calculated for NTGR (48% +- 7%).
11	PGE	63	**Free-ridership scoring:** Table 6-2 provides the participant free-ridership scoring elements, but it is complicated to follow. Could DNV please provide a couple of examples to walk the reader through the process to aid the PAs in future program improvements? For example, if a participant adopts a high efficiency gas water heater at burnout rather than a regular efficiency gas water heater without a rebate, what would be the score? If a participant adopts a high efficiency gas water heater now, rather than a regular efficiency gas water heater without a rebate in 12 months, or 24 months, or 48 months what would the scores? And, for fuel switching (Table 6-3 on page 64), what would similar examples be if the same participant adopted an electric heat pump instead?	If a participant adopts a high efficiency conventional gas storage tank water heater, but would have purchased a standard efficiency conventional gas storage tank water heater without the rebate, the efficiency dimension of free-ridership would equal 0 because the consumption of the water heater that would have been purchased without the rebate is equal to the consumption of a standard efficiency conventional gas storage tank water heater, the assumed baseline technology. If a participant adopts a high efficiency gas tankless water heater, but would have purchased a standard efficiency gas tankless water heater without the rebate, the efficiency dimension of free-ridership would equal 0.5 because the consumption of the water heater that would have been purchased without the rebate is greater than the consumption of the adopted water heater and less than the consumption of a standard efficiency conventional gas storage tank water heater, the assumed baseline technology. If a participant adopts a high efficiency heat pump, but would have purchased a high efficiency gas condensing water heater without the rebate, the efficiency dimension of free-ridership would equal 0.5 because the consumption of the water heater that would have been purchased without the rebate is greater than the consumption of the adopted water heater and less than the consumption of a standard efficiency conventional gas storage tank water heater, the assumed baseline technology. Table 6.3 shows the score for the efficiency dimension of free-ridership for all permutations assessed in the survey data where the participant would have purchased a different technology, fuel type, or efficiency without the rebate, including each of the examples above. The timing dimension of free-ridership equals 1 if the water heater would have been purchased at the same time or sooner without the rebate. For occupants, the timing dimension of free-ridership equals 0 if the water heater would have been purchased more than 24 months later without the rebate. If the water heater would have been purchased 12 months later without the rebate, the timing dimension of free-ridership would equal 0.5 ((24 months - 12 months) / 24 months). For this question, possible responses include at the same time or sooner, more than 24 months later, or a value between 1 thru 24 on a sliding scale. Therefore, occupants cannot respond 48 months later. Instead the response would be more than 24 months later. Similarly for property managers, the timing dimension of free-ridership equals 0 if

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				the water heater would have been purchased more than 48 months later without the rebate. If the water heater would have been purchased 12 months later without the rebate, the timing dimension of free-ridership would equal 0.75 ((48 months - 12 months) / 48 months). Using the same equation, if the water heater would have been purchased 24 months later without the rebate, the timing dimension of free-ridership would equal 0.5.
12	PGE	survey instruments	**PDFs not readable:** Could DNV please provide readable versions of the survey instruments as appendices in the final evaluation report? As produced now these are just graphics of icons.	Noted. Thank you. The updated report has PDF documents as attachments within the main report.
13	SCE		How reliable is the survey-based approach for calculating the savings? We think actual meter-based savings would be most appropriate considering that ex-ante values would lead biased estimates.	We did not estimate (gross) savings using our survey results. We only explored the reasonableness of the UES values reported in the tracking data, which reflects the scope of the evaluation.
14	SCE		How do you think self-reporting and self-selection to the survey may contribute the estimating survey-based results?	It is possible that survey data have sample and response bias. Since program participants opt-in to receive incentivized water heating measures through the programs, there is self-selection implicit in any estimates based on even on a census of participants. Furthermore, a subset of these program participants choose to respond to the survey, compounding the self-selection. In order to minimize the latter bias, post-hoc sample weights are applied to ensure the sample is representative of the population along known and relevant dimensions such as location and consumption that affect metrics of interest. With respect to bias in self-reported responses, best practices in survey design are employed to minimize this bias. DNV's response rates were greater than 15% for each PA for the participant surveys which inform the NTGRs. This is much better than is currently being realized in most internet-based public opinion research. According to a Pew report (https://www.pewresearch.org/politics/2012/05/15/assessing-the-representativeness-of-public-opinion-surveys/) in 2012, response rates were 9% and showed a consistently declining trend since 1997.
15	SCE		Based on the small sample size for SCE participants, what kind inferences can SCE make from 2 participant responses?	We made inferences based on overall survey responses. SCE's water heating program provided heat pump water heaters, and responses from program participants across all PAs that received heat pump water heaters informed the inferences we made, which we believe provides valid results.
16	SCE		Do you think low survey participation for property managers can be associated with the low incentive amount? How $100 can help, incentives the property managers to spend time with the surveyors?	Central system measures include both central water heaters (tankless and storage) and water heater controls (recirculation pumps and boiler controllers). Property manager response rates that cover these measures were robust (15%) and the incentive level provided did have an impact on this aspect of the survey.
17	SCE		What percentage of MF central systems costs are covered by SoCalGas incentives? Were there any free central system offerings to MF Properties? Are they accounted in this study?	The evaluation did not include a study of the proportion of costs offset by incentives. We cannot comment on whether any systems were "free" offerings nor how many there may have been.
18	SCE		The study did not evaluate cost effectiveness. What is the cost effectiveness of the MF measures? Is this another	The scope of this evaluation does not include an examination of cost effectiveness.

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			example of less than prudent use of rate payers' funds to further perpetuate the use of gas water heating by SoCalGas?	
19	SCE		The study notes that early retirement of recent tankless gas installations will be necessary to achieve California's carbon reduction goals. Does this imply that it is not best use of funds to continue offering incentives for these units? How do you explain this phenomenon?	This study recommendation looks forward and notes that from the perspective of the Energy Efficiency proceeding long-lived gas efficiency savings are a specific target, but there is a change to the fuel substitution test which occurred right after PY2019. From a program recommendation standpoint, it is notable that there may be fewer replace on burnouts if retrofitting from tank to tankless extends EUL and there are new incentives for HPWH coming for programs 2020 and beyond (Fuel Substitution, SGIP, TECH). Additional research and analysis will be required to inform changes in the allocation of resources to incentivize energy efficiency in water heating measures.
20	SCE		The $1,200 incentive level showed a significant increase in the response of non-participants who said they would purchase the high efficiency model. Why was this data point not addressed? Much higher incentives may be needed to overcome the barriers for high efficiency heat pump water heaters that include perceived high upfront costs, unfamiliarity with the technology, and competing natural gas water heater incentives (as long as they are offered).	Edits made. Text now includes the following: *"Only 16% of non-participants said they would purchase the high efficiency model with no incentive. Over four-fifths (81%) said they would purchase the high efficiency model with a $1,200 incentive."*
21	SCE	6	***A report key finding states, "Rebates have a modest impact on motivation to install water heating technologies for single-family programs."***: The finding and discussion does not address how rebates can impact the motivation to substitute the gas water heater with an electric heat pump water heater, i.e. fuel substitution. This is partially addressed on Pg. 9 in the finding "There is work to do to overcome barriers to water heating electrification." High upfront costs, including panel upgrades, are described as a barrier that may be addressed with higher rebates. The report does not address the barrier created by competing incentives for natural gas storage water heaters and natural gas tankless water heaters. The natural gas water heater incentives act as disincentives for installers and customers to choose to electrify water heating.	Note that this program was implemented prior to the change in fuel substitution rules (2019) and there were few competing incentives. Water heating programs aim to ensure installation of efficient natural gas water heaters for customer segments for whom current costs of heat pumps render them out of reach, while at the same time boosting adoption of heat pump water heaters for customers for whom the incentives make this emerging technology a competitive alternative. As stated in a previous comment response, fuel substitution opens an alternative path to gas savings as well as additional incentives and recent activity pushing high efficiency tankless has implications as policy changes. The study was not designed to look at the barrier of competing market messages and thus did not have data to support discussion of this topic.
22	SCE	22	***Table 4-4 Age of replaced water heaters****:* For the Heat Pump Water Heater category, how were the percentages calculated for each category of Age of Replaced Unit? For a sample size of 9, the listed percentages do not seem possible.	The percentages in the table are not simple averages, but are weighted averages that balance the participant survey sample to the population proportions by fuel, climate zone group, and consumption level combinations. Appendix F provides the weights used for this purpose.
23	SCE	22	***EUL*** – Study findings suggest that "*the age of the majority (66%) of natural gas storage water heaters that were replaced exceeded the EUL value of 10 years specified by the California Database for Energy Efficiency Resources (DEER), while the age of the majority (> 78%) of natural gas*	(Table 44) We agree with the recommendation to retain the 10 year EUL for HPWHs due to small sample size. However, the relatively high early failure rate for this small sample should be a significant concern due to the anticipated promotion of HPWHs in current and future programs, so the EUL of HPWHs should be targeted for research. Although not mentioned in the comment, the tankless water

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			tankless water heaters replaced was well below the DEER-specified EUL value of 20 years. The age of about half (53%) of heat pumps replaced was less than the DEER-specified EUL value of 10 years. The finding related to age of replaced heat pumps should be interpreted with caution given the low sample size". Recommendation: Age of replaced unit alone (excluding statistically significant sampling on survival rate and/or equipment degradation and/or persistence) may not be sufficient to adequately determine and/or recommend adjustments to technology's EUL – recommendation: retain existing EUL for HPWH technology.	heater EUL should also be investigated to determine whether a reduction in EUL from 20 years is warranted.
24	SCE	27	***Table 4-7***. Program attribution (NTGR) by PA Measure suggest NTGR values for fuel substitution measures of less than 100% – Recommendation: Specifically for fuel substitution measures (providing EE and direct GHG benefits) – and given challenges influencing customers to transition between fuel-regulated technologies (e.g., from gas to electric hot water heat) and given that top motivation influencing customer is not "good for the environment", it is recommended for NTG to be retain at 1.0 as directed in fuel substitution technical guide – "NTG – FuelSubst-Default"	An NTGR of 1.0 is currently a policy-specified (versus evaluation-derived) value as directed in the fuel substitution guidance memo. There is currently no plan to revise the NTGR and the HPWH sample size is too small to be used for that purpose. However as with the previous HPWH comments, these findings are a preview for future evaluations and should be considered for program design, offerings, and even tracking data.
25	SCG	Table 4-1	Sample disposition for participant and non-participant surveys shows a 2% response rate for non-participant across all investor-owned utilities ("IOU"). Although the total completed count for non-participant is more than the total completed count for participant, the rate is significantly low: 2% vs. 15% and higher (for participant). SoCalGas understands that the COVID-19 pandemic has caused difficulties in reaching the customers for survey, but the difference in percentage could alter your conclusions and findings in the analysis. This is a concern, especially when the survey results yield a significant difference in awareness between participants and non-participants in program (Demand response, Figure 4-10) and technology (Figure 4-20) awareness and are not closely aligned with the 2019 RASS survey in Hot water use (table 4-10).	Although the overall response rate is low for the non-participant survey, the sample size is robust enough to enable balancing the survey sample along key relevant population dimensions such as climate zone and consumption. As we note in the report, the sample required minor adjustments due to over or under representation along these dimensions. In terms of the difference in interest in demand response programs (Figure 4-10), while the difference is statistically significant at 54% and 64% for non-participants, this is not a sizeable and material difference. The key point of this figure is that over half of the market indicates interest in these demand response programs, be they participants or non-participants. In terms of the difference from the RASS results, the PY2019 water heating evaluation samples for both participants and non-participants have a different composition than the RASS sample.
26	SCG	Table 4-2	Sample disposition for property manager survey shows only numbers for SoCalGas, with 102 completed. In section 4.3.1.1, it states that "the DNV GL team conducted primary research with 114 property managers (projects) to determine program influence on installation of measures..." Does this mean only 12 property managers are other IOUs' customers? How could conclusions, findings, and recommendations be drawn for all IOUs from such survey sample without subject	Edits made to update the number to 114 in the sample disposition table. Only SCG and MCE had claims involving property managers. Since there were only 4 such claims from MCE, all property manager interviews are in SCG service territory.

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			to SoCalGas service territories only? What are the reasons that other IOUs' property managers were not surveyed?	
27	SCG	Table 4-3	Demographic profile of non-participant and participant survey respondents show respondent percentages that do not correlate with California American Community Survey's demographic characteristics, especially in dwelling type, language, and education. What conclusion does DNV GL have on this? Do the results help to bring up what the program administrators ("PA") are looking for in California market when the survey sample does not represent the demographics of the general population?	These are opt-in programs and the demographic profiles of program participants and the subset that choose to respond to the survey will thus not reflect the general population in California. We juxtapose the demographic of the survey respondents with those of the California American Community Survey to provide information on the types of participants that opt-in the PA's PY2019 water heating programs.
28	SCG		Are customers asking for a higher efficient model during emergency replacement? Nothing was noted in the report whether the rebate played a factor during emergency replacement for storage water heaters, which could support the findings that rebates help influence water heater purchase for single family. Also, would the models of the emergency replacement make a difference in the decision making process?	The program influence on efficiency for natural gas storage water heaters is similar for customers that replaced a water heater due to emergency replacement and those that replaced a water heater for another reason. However, free-ridership is higher among early replacement due to timing of the purchase.
29	SCG	6	Below are recommendations on Page 6. While Net to Gross Ratios ("NTGR") for all multi-family measures mentioned below are shown as 100% or close to 100% (Table 4-6), the reasons behind these recommendations are not persuasive. The first one says the NTGRs to be applied, and the second says the NTGRs should not be applied, which ultimately means that no adjustments should be made. If the NTGRs for system storage and tankless water heaters are not 100%, will DNV GL still provide the IOUs with the same recommendation, even with the same low sample size? Would it be more appropriate to make a recommendation based on the NTGR itself? A low sample size would indicate that the result might not be statistically accurate. "***We recommend that NTGRs from the evaluation be applied to PY2019 claimed savings for recirculation pump controls and boiler controllers.*** ***Given the low sample size for multifamily central system storage and tankless water heaters, we recommend no adjustments be made to NTGRs for PY2019 claims.***"	Our recommendations are on a measure-by-measure basis and based on sample size and relative precision. Our recommendations to apply the evaluated NTGR does not change based on the value of the NTGR itself. For these specific measures, recirculation pump controls and boiler controllers each had sample sizes greater than 40. We typically look for sample sizes greater than or equal to 30 based on the Central Limit Theorem. They also had relative precisions less than or equal to 10%. Therefore we consider these estimates robust. In contrast, the central system measures had relative precisions less than 10%, but sample size is less than 5 for each. We do not consider an estimate with that small of a sample size to be robust. Therefore we did not recommend changing the ex-ante NTGR for these measures.
30	SCG	6	NTGRs for SoCalGas Tankless Water Heater suggested by the DNV GL report are extremely low, from 36.4% to 40.1% (Table 4-7). DNV GL recommended (page 6-see below) to apply these NTGRs to claimed savings value, while acknowledging that the timing of purchases is strongly affected by existing equipment failure or malfunction rather than program incentives. The recommendation of a lower	See response to comment #5. The free-ridership calculation never penalizes for lack of acceleration of a project.

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			NTGR was based on the timing of the purchase. A finding in the report states that “rebates have a modest impact ... for single family programs” since “timing of the purchases is strongly affected by equipment failure rather than the program” (Page 6). SoCalGas does not agree with the conclusion since SoCalGas had a 50% kicker incentive in program year 2020. This should be re-evaluated in the next study. "***We recommend that NTGRs from the evaluation be applied to PY2019 claimed savings for HPWHs, storage, and tankless water heaters.***"	
31	SDGE	Section 2.1 and Survey	When asking "Would have purchased a minimum standard efficiency water heater?", leaving in the word "minimum" highlights a standard efficiency piece of equipment as lesser than a "high efficiency piece of equipment". Words like "minimum" and "high" could result in bias in the respondent's answer. Recommend rephrasing to: "Would have purchased a standard efficiency water heater?" and "Would have purchased the same efficiency water heater."	We agree with the suggested survey wording change and will incorporate this suggested edit for surveys to evaluate PY2020 and beyond. We did go through stakeholder review of the PY2019 instrument and this point was not raised at that time.
32	SDGE	Section 2.1	People who answered this survey have already purchased the equipment and seen the benefits of the new installations. When asking these questions, the respondents have their answers impacted by hindsight. When respondents are then asked "would they have purchased the equipment without program incentives," for respondents happy with their purchase, they would likely purchase the same equipment again without incentives because they have already experienced the benefits from the system. This type of question can only be truly answered at the time of purchase when the customer is weighing the options versus the cost of the available systems without experiencing the benefits.	This is a known and acknowledged limitation to after-the-fact surveys. Obtaining answers to such questions at the time of purchase is impractical. Furthermore, potential bias can always be identified for any method. For a time-of-purchase survey, respondents could be biased by an interpretation that a free-rider answer could invalidate their rebate. Furthermore, past studies have shown that customers have decided on their energy efficient purchases prior to making the purchase at the store. *"A majority of participants (73% overall) reported they had decided to purchase an Energy Star or energy-efficient product before they became aware of the program*." The corresponding measure level statistic for storage water heaters is 62%. (Pg. 34 and 35, SoCalGas 2010-2011 Residential Program Process Evaluation, http://www.calmac.org/publications/SCG_Res_Program_Process_Eval_FINAL.pdf)
33	SDGE	Section 4	Multifamily property owners are less likely to have a personal bias affecting their response because their decisions are more likely to be attributed cost effectiveness since they are running a business where profitability is essential. Purchasing desires are less likely to be impacted by personality bias and more impacted by a financial bias. Were biases accounted for in the survey results?	The surveys were designed to reach and gather data from decision makers - property managers in the case where they were responsible for installation of measures in several units and occupants where they were responsible for installation of measures in their own residence. The only way to account for such biases is with a truly randomized experimental program design. Those are only implemented in very limited circumstances (e.g. Home Energy Reports). The survey included several qualitative questions to help validate the scored NTGR results. Those answers were aligned with the NTGR scores. The report describes those additional results.

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34	SDGE	Slide Deck 20	Results suggest that the energy savings from deemed workpapers may be overestimated. This was a rough analysis but the evaluation warrants to review savings calculations. The CPUC water heating calculator was recently updated in 2020, did the evaluation team review these changes?	The study does not provide estimates of gross savings and only includes adjustment factors for net savings. Updates to the water heater calculator would not apply to PY2019 claims.
35	SDGE	Slide Deck 35	A recommendation was to increase rebate levels, which would increase participation based on survey results. However, was there any analysis by the evaluation team to conduct cost effective analysis when making these recommendations? Did the amounts in the survey go over the IMC for certain water heater technologies?	A study of cost effectiveness is not included in the scope of work for this study. Survey responses provide directional insight and further research and analysis will be required to implement any program changes such as increased incentives for water heating measures.
36	SDGE	9	The report states that "the cost to replace an electrical panel averages $1,138, with a typical range of $498—$1,781". Footnote 19 should be added to this statement.	Edits made. Text now reads, *"A scan of the third-party platform, HomeAdvisor, which connects homeowners to home service professionals to complete home projects shows that costs to replace an electrical panel average around $1,138, with a typical range of $498 to $1,781."*
37	SDGE	31	Figure 4-10 shows that non-participants are more interested in participating in water heater demand response programs than participants. Is there any insight from the evaluation on why that could be?	The difference between the percent of participants (54%) and non-participants (64%) who expressed interest in a water heater demand response program is statistically significant at the 90% confidence level. However, the magnitude of the difference (10 percentage points) is not sizable. The key takeaway is that more than half of all respondents (participants and non-participants) expressed interest in a water heater demand response program.