SAFER, SMARTER, GREENER

Impact Evaluation Report

Residential HVAC Sector – Program Year 2019

EM&V Group A

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1 EXECUTIVE SUMMARY

This report presents the electric and natural gas energy savings evaluation of residential heating, ventilation, and air conditioning (HVAC) equipment in ratepayer-funded energy-efficiency programs in Program Year (PY) 2019. DNV GL estimated energy and demand savings for six selected HVAC technology groups across programs offered by the following program administrators (PAs): San Diego Gas and Electric Company (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), and Pacific Gas and Electric Company (PG&E). We conducted this evaluation as part of the California Public Utilities Commission (CPUC) Energy Division (ED) Evaluation, Measurement & Verification contract.

The primary goals of this PY2019 evaluation were to:

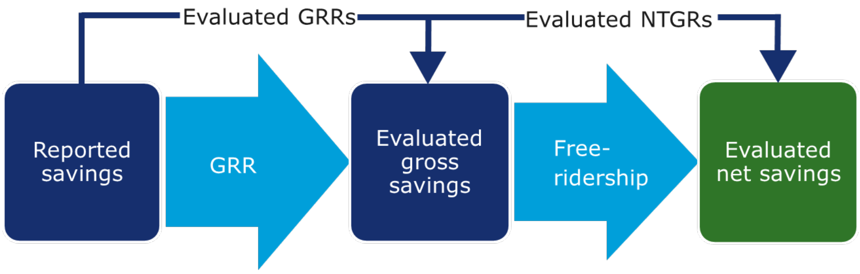
- Assess savings for electric demand in kilowatts (kW), electric consumption in kilowatt-hours (kWh), and gas consumption in therms with a focus on quantifying peak demand impacts of the selected HVAC technologies.
- Determine the savings that occur as a result of the program with respect to end-users, customer decision makers, and distributors.
- Provide insights into how evaluated HVAC technologies are producing energy savings cost-effectively and what improvements can be made to move towards strategic statewide energy-efficiency goals.

Central to this evaluation was collecting data from participating end-users, customer decision makers (those who make the decision to implement an energy efficiency project), and distributors to adjust key technical parameters that affect the calculation of energy and demand savings.

The first major step was estimating the gross savings for each of the six evaluated technologies. Gross savings are the changes in energy and power demand that resulted from energy-efficiency program activities, regardless of what factors may have motivated the program participants to take actions. We compared the evaluated gross savings with the gross savings reported by PAs to develop ratios of the evaluated savings estimated to the PA-reported savings values, which are referred to as gross realization rates (GRRs).

We also estimated the amount of savings that resulted from the program. This estimate is developed by first estimating the amount of “free-ridership.” This represents the savings that would have occurred without the incentive being provided (e.g., because the customer indicates s/he would have purchased the equipment at full cost if the incentive had not been offered). From this, net-to-gross ratios (NTGRs) can be estimated for each of the evaluated technologies by subtracting the free ridership savings from the gross savings and dividing by gross savings. An evaluated NTGR of 100% would indicate that the energy and gas savings were completely due to the influence of the incentive offered by the program. A score less than 100% means that other factors were responsible for the energy savings. Figure 1-1 illustrates how evaluated net savings is developed.

Figure 1-1. Energy savings evaluation process: getting from gross to net



NTGR values are used to calculate the evaluated technologies' net savings, which tell us how much impact the program had on the evaluated technologies' electricity and gas savings. The net realization rate (NRR) removes the savings from installations that would have happened even if there were no rebates and is calculated as the ratio of the evaluated net savings value to the PA-reported net savings value. Thus, the NRR indicates the true impact of the ratepayer-funded program. The higher the NRR value, the greater the program's influence and achieved savings.

1.1 Study background and approach

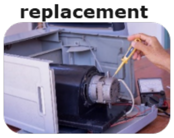
Figure 1-2 summarizes the six residential HVAC technologies selected for evaluation.

Figure 1-2. Summary of evaluated technologies

The PY 2019 gross savings evaluation approach for the six selected HVAC technologies is built on a combination of two established program evaluation methods: analysis of advanced metering infrastructure (AMI) data and energy simulation modeling. We created engineering simulations of all the evaluated technology combinations because the technologies interact with each other and affect the total savings and savings fraction apportioned to each technology. We also analyzed AMI consumption data to determine the participating households' annual electrical and gas savings based on a pre-/post-retrofit energy consumption analysis. We joined the household-level AMI-based savings and apportion the actual savings values to technology groups based on the proportions derived from the simulation results.

Net savings were estimated from web-based surveys of single-family residents or phone-based surveys of other customer decision makers (like multifamily property managers) and from interviews with program participating equipment manufacturers and distributors. The various data collection and analysis methods we used to calculate the savings of the selected HVAC technologies are summarized in Figure 1-3.

Figure 1-3. Key data collection sources and activities by technology group

	Phone interview	Web survey	Data review	Data analysis
Coil cleaning 	Multifamily property managers N=2,060 n=77	Customers N=15,234 n=510	Customer and site data	Consumption data ⚡ N=28,367 n=15,338
Duct testing and sealing 	Multifamily property managers N=698 n=65	Customers N=8,421 n=381	Customer and site data	Consumption data ⚡ N=8,592 n=3,317 🔥 N=8,592 n=1,118
Fan motor controls 	Multifamily property managers N=1,591 n=74	Customers N=18,182 n=632	Customer and site data	Consumption data ⚡ N=32,991 n=16,640 🔥 N=4,291 n=116
Fan motor replacement 	Multifamily property managers N=1,665 n=69	Customers N=13,970 n=580	Customer and site data	Consumption data ⚡ N=13,916 n=6,877 🔥 N=12,972 n=178
Furnaces 	Manufacturers and distributors N=14 n=3	Customers N=967 n=28	Customer and site data	Consumption data 🔥 N=796 n=482
RCA 	Multifamily property managers N=1,027 n=74	Customers N=11,439 n=390	Customer and site data	Consumption data ⚡ N=23,018 n=12,577

N=population; n=number of participants; the lightning bolt symbol=electric and the flame symbol=gas

1.2 Evaluated savings results

The next sections present more detailed results of the gross and net savings evaluation by HVAC technology group, followed by a summary of key findings.

1.2.1 Coil cleaning

An air conditioner's condensing coil removes heat that was captured indoors by transferring it to outside air. The coil works best when that outside air can be drawn easily through it. Cleaning the condenser coil helps ensure that heat is efficiently transferred from the system to the ambient air. Coil cleaning was offered by PG&E and SDG&E through direct install programs.

Table 1-1. presents the PY2019 statewide savings summary for the residential coil cleaning technology group. Overall, the electric consumption (kWh), peak demand (kW), and gas consumption (therms) GRRs for this technology are 130%, 95%, and 0%, respectively. The findings show more electrical energy and demand savings was realized than the programs reported, while also finding no gas energy (therm) penalty for coil cleaning. The results are consistent with previous evaluation effort findings that coil cleaning provides a small amount of electrical energy savings but with non-negligible uncertainty.

The results of the web and phone surveys indicate the NTGRs for the coil cleaning technology group are 79% for kWh, 78% for kW, and 83% for therms. These reported NTGR values are significantly higher than the PA reported values of 66%, 67%, and 65% for kWh, kW, and therms respectively. We expected this high degree of program attribution since surveys showed that most customer decision makers are unaware of the benefits of condensing coil cleaning and they said the program influenced their decision to receive coil cleaning because the service was low- or no-cost to them through PA's direct install mechanism.

The NRRs for the coil cleaning technology group, which considers both the evaluated GRRs and NTGRs are 154% for kWh, 111% for kW, and 0% for therms.

Table 1-1. Statewide first-year savings summary by fuel for coil cleaning

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
505,680	130%	657,306	66%	79%	336,230	517,243	154%
Peak electric demand (kW)							
520	95%	492	67%	78%	346	383	111%
Gas consumption (Therm)							
-57	0%	0	65%	83%	-37	0	0%

1.2.2 Duct testing and sealing

Duct testing and sealing involves testing and sealing residential ductworks to reduce leakage losses to specified levels. By reducing leakage, more of the heating or cooling is delivered directly to the occupied space rather than lost to leakage outside the occupied space. These measures are provided by PG&E, SCE, and SCG through direct install programs.

Table 1-2. presents the PY2019 statewide savings summary for the residential duct testing and sealing technology. Overall, the kWh, kW, and therms GRRs for this technology are 67%, 14%, and 75%, respectively. These results are lower than, but similar to, PY2018 duct testing and sealing evaluation results. This is because this year's sample considers participants claiming multiple evaluated technologies where the technologies have interactive effects[1] and the overall household-level savings developed under this evaluation is less than the sum of the PA reported savings at the household-level.

The results of the web and phone surveys indicate the NTGRs for the duct testing and sealing technology group are 95% for kWh, 96% for kW, and 94% for therms. These evaluated NTGR values are higher than the PA reported values of 85%, but in line with PY2018 evaluated NTGR values for the duct sealing and testing technology group. Like the coil cleaning technology group, most customer decision makers are not aware of the benefits of duct testing and sealing and likely would not think to have their duct systems tested and sealed on their own. Survey results suggest that the high NTGRs for this technology group are also due to the programs delivering the technology to them at reduced or no-cost via a direct install approach. The NRRs for the duct testing and sealing technology group, which considers both the evaluated GRRs and NTGRs, are 75% for kWh, 16% for kW, and 83% for therms.

Table 1-2. Statewide first-year savings summary by fuel for duct sealing and testing

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
2,178,922	67%	1,452,756	85%	95%	1,844,197	1,384,845	75%
Peak electric demand (kW)							
2,897	14%	408	85%	96%	2,453	390	16%
Gas consumption (Therm)							
150,647	75%	112,912	85%	94%	127,539	105,913	83%

1.2.3 Fan motor controls

A fan motor control is a retrofit add-on measure that delays turning off the fan motor at the end of an air conditioning or heating cycle to increase the HVAC system's effectiveness by extracting the remaining cooling or heating potential. This measure only applies to older HVAC systems; newer systems already include this feature. These measures are provided by PG&E, SCE, SCG, and SDG&E through direct install programs.

Table 1-3 presents the PY2019 statewide savings summary for the residential fan controls technology. Overall, the kWh, peak kW, and therms GRRs for this technology are 19%, 13%, and 0%, respectively. The low electricity savings may result from the competing effects of this technology and smart communicating thermostats, both of which are capable of delaying fan turn-

[1] Interactive effects refer to the indirect effect on equipment energy usage due to installation of multiple energy efficient technologies. For example, The decline in heat emitted from high efficiency lighting technology may lead to an increase in heating usage and a decrease in cooling usage.

off and were often reportedly installed together. The analysis produced no appreciable gas savings for the heating focused SCG fan motor controller technology.

Generally, we found that fan controls NTGRs are higher than reported. The overall state-wide evaluated NTGRs are 88% for kWh and 88% for kW, showing that the programs had a strong influence on customers installing the fan control technology. Surveys with the participants revealed that the program offered them a reduced-cost or no-cost opportunity to install this technology, and that this technology is not well known to typical customer decision makers. Several customer decision makers said their existing fan motor needed maintenance and this technology upgrade came highly recommended from the HVAC contractor as a way to reduce their energy bills. The evaluation did not receive any survey responses from the SCG furnace (therm) focused fan motor controls recipients so the reported value of 90% for therms is retained.

The net realization rates for the coil cleaning technology group, which considers both the evaluated GRRs and NTGRs are 25% for kWh, 18% for kW, and 0% for therms.

Table 1-3. Statewide first-year savings summary by fuel for fan motor controls

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
8,477,580	19%	1,579,743	65%	88%	5,485,134	1,383,974	25%
Peak electric demand (kW)							
3,955	13%	514	63%	88%	2,509	450	18%
Gas consumption (Therm)							
2,532	0%	0	90%	90%	2,278	0	0%

1.2.4 Fan motor replacement

The fan motor replacement technology involves the replacement of existing permanent split-capacitor central HVAC fan motors with high-efficiency brushless fan motors. These brushless fan motors consume less electrical energy to move air through the HVAC system thus savings kWh energy and peak demand kW. A consequence of this lower electrical draw is a reduction in heat off the motor, which is beneficial to cooling but a detriment to heating and thus the fan motor replacement technology has a negative savings impact on gas (therm) energy. Fan motor replacements are delivered by PG&E, SCE, and SDG&E via direct install programs.

Table 1-4 presents the PY2019 statewide savings summary for the residential fan motor replacement technology group. Overall, the kWh, peak kW, and gas therms GRRs for this technology are 27%, 17%, and 29%, respectively. This means both the evaluated energy and demand savings are lower than the PA-reported savings. This is due to the consideration of interactive effects among the multiple technologies installed and because the analysis shows that less savings is realized at the household-level than the sum of expected saving for the measures installed at the household-level.

The results of the web and phone surveys indicate the NTGRs for the fan motor replacement technology group are 90% for kWh, 91% for kW, and 91% for therms. These evaluated NTGR values are significantly higher than the PA reported values of 67%, 65%, and 63% for kWh, kW, and therms respectively. High attribution for this technology is expected as it provides a low- or no-cost upgrade through a direct install mechanism for a measure that is relatively unknown to typical residential end-users. Our net surveys revealed that a high number of program participants needed the program incentive to upgrade their fan motors, and most of residential end-users also said they wouldn't have known to install the high-efficiency fan motor without program outreach.

The NRRs for the coil cleaning technology group, which considers both the evaluated GRRs and NTGRs are 36% for kWh, 24% for kW, and 42% for therms.

Table 1-4. Statewide first-year savings summary by fuel for fan motor replacement

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
7,926,616	27%	2,142,370	67%	90%	5,316,403	1,930,217	36%
Peak electric demand (kW)							
6,263	17%	1,067	65%	91%	4,050	975	24%
Gas consumption (Therm)							
-36,823	29%	-10,760	63%	91%	-23,187	-9,802	42%

1.2.5 Furnaces

For upstream furnace programs, furnace manufacturers and distributors are offered incentives by the PAs to stock and sell high-efficiency furnaces with the aim of reducing customers' final cost, thereby encouraging customers to purchase high-efficiency rather than standard-efficiency equipment. SCG and SDG&E both offer upstream programs. SCG also provides a downstream program delivery, providing incentives directly to the purchaser.

Table 1-5 presents the PY2019 statewide savings summary for the residential furnace technology group. Overall, the gas therms GRR for this technology is 14%. This result is driven by the outcome of the analysis of high efficiency central furnaces only realizing slightly less than half of their reported saving and the evaluation team's assigning a GRR of 0% for the gravity wall furnace technology due to inadequate program design and reporting documentation that precludes analysis of these furnaces.

The results of the web and phone surveys indicate the NTGRs for the residential furnace technology group is 28% for therms. The low NTGR for the furnace technology, relative to the other groups studied in this report, is not surprising because unlike those technologies, furnaces are delivered as replacements for broken equipment—not optional add-ons or maintenance services, furnaces are well known to customer decision makers, and furnaces are high-cost durable goods that the programs incentivize only marginal efficiency improvement and not most or all of the cost of the technology. Surveys revealed that a high number of participants would have installed the same efficient furnace without the program incentive.

The net realization rates for the technology group, which considers both the evaluated GRRs and NTGRs, is 6% for therms.

Table 1-5. Statewide first-year savings summary by fuel for furnace

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
0	0	0	n/a	n/a	0	0	n/a
Peak electric demand (kW)							
0	0	0	n/a	n/a	0	0	n/a
Gas consumption (Therm)							
197,494	14%	27,479	60%	28%	118,497	7,646	6%

1.2.6 Refrigerant charge adjustment (RCA)

Refrigerant charge adjustments involve measuring and correcting the amount of refrigerant within the air conditioning system. Over- or under-charged equipment operates less efficiently than properly charged systems, so adjusting the charge can save energy. PG&E and SDG&E reported RCA savings through their residential direct install programs.

Table 1-6 presents the PY2019 statewide savings summary for the residential RCA technology group. Overall, the electric consumption (kWh), peak demand (kW), and gas consumption (therms) gross realization rates for this technology are 4%, 2%, and 0%, respectively. The low realization rate is a result of two drivers: the impacts of RCA as modeled are the smallest of any of the technology groups evaluated, and second, total evaluated household savings are smaller than the sum of reported savings. Even though our simulations assumed that the typical system is 12% undercharged (based on studies HVAC3[2] and HVAC5[3]) rather than the 8% assumed by PA workpapers, the savings are lower than reported.

Table 1-6. Statewide first-year savings summary by fuel for RCA

Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Reported Net Savings	Evaluated Net Savings	NRR
Electric consumption (kWh)							
2,244,666	4%	94,255	84%	84%	1,877,110	79,228	4%
Peak electric demand (kW)							
2,366	2%	47	83%	84%	1,965	40	2%
Gas consumption (Therm)							
-115	0%	0	83%	84%	-96	0	0%

The results of the web and phone surveys indicate the NTGRs for the RCA technology group is 84% for kWh, kW, and therms. These evaluated NTGR values are not significantly different than the PA reported values of 84%, 83%, and 83% for kWh, kW, and therms respectively. High program

[2] NV GL, 2017, Impact Evaluation of 2015 Commercial Quality Maintenance Programs (HVAC3), California Public Utilities Commission (CALMAC ID: CPU0117.04

[3] Op. cit. California Public Utilities Commission (CALMAC ID: CPU0159.01)

attribution scores for this technology are expected as the program offers this technology to the residential end-users with low to no cost via direct install approach.

The net realization rates for the coil cleaning technology group, which considers both the evaluated GRRs and NTGRs, are 4% for kWh, 2% for kW, and 0% for therms.

1.3 Study recommendations

- DNV GL recommends the PAs review their furnace technology offerings for viability. The reported gross savings was not considerably realized—even without considering the wholly unrealized savings from the gravity wall furnace technology. The upstream programs' lower NTGR reflects their lack of influence. The preponderance of claims was for gravity wall furnaces; the incentives for gravity wall furnaces went directly to the manufacturer and had no direct effect on the price they charged their distributors. The manufacturer indicated only a 20% increase in sales of high efficiency gravity wall furnaces result from the program.
- DNV GL recommends the PAs should investigate the savings for the refrigerant charge adjustment (RCA) technology group and consider discontinuing any HVAC maintenance offering that promotes refrigerant charge adjustments as the evaluation found little impact for this technology group. These results are in line with the 2015 Quality Maintenance (QM) HVAC impact evaluation results where HVAC maintenance programs focusing on RCA provided minimal energy savings with high uncertainty.
- With a high NTGR, DNV GL recommends PAs incorporate the direct-install design components of these residential HVAC programs when offering additional energy saving technology that is unfamiliar to most customers, like the coil cleaning, duct sealing, fan controls, and fan motor replacement technology groups in this instance.
- We recommend PAs further study whether the Smart Communicating Thermostat technology provide the same delayed-shutoff function as separate fan controls technology group, and if so, adjust expected savings or eligibility for both technologies.

2 INTRODUCTION

The report presents DNV GL's energy savings estimates (impact evaluation) of residential heating, ventilating, and air conditioning (HVAC) technology groups (measures) that are part of the California Public Utilities Commission (CPUC) HVAC Research Roadmap. These programs are evaluated under CPUC's Group A evaluation contract group. The primary results of this evaluation are estimated energy savings (in kWh, kW, and therms) achieved by six selected measures in Program Year 2019 (PY2019) HVAC residential programs. The programs are offered by the following California program administrators (PAs): San Diego Gas and Electric Company (SDG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), and Pacific Gas and Electric Company (PG&E).

2.1 Evaluation objectives and researchable issues

The primary objective of this evaluation is to assess the gross and net kWh, kW, and therm savings achieved from the statewide list of HVAC Efficiency Savings and Performance Incentive (ESPI) uncertain measure groups. The focus is on six selected measure groups across the HVAC portfolio from the 2019 programs offered by SDG&E, SCG, SCE, and PG&E. The evaluated measures are described in greater detail in the next section.

The priorities of this evaluation effort, and the researchable issues this evaluation seeks to examine, are:

1. Determine reasons for differences between evaluated (ex post) and reported (ex ante) savings, and as necessary, assess how to improve the ratio of evaluated savings to predicted savings (realization rates). Identify issues with respect to reported impact methods, inputs, procedures and make recommendations to improve savings estimates and realization rates of the evaluated measure groups.
2. Provide results and data that will assist with updating relevant workpapers and the California Database for Energy Efficiency Resources (DEER) values.
3. Estimate the proportion of program-supported measure groups that would have been installed absent program support (free-ridership), determine the factors that characterize free-ridership, and as necessary, provide recommendations on how free-ridership could be reduced.
4. Provide timely feedback to the CPUC, PAs, and other study stakeholders to facilitate timely program improvements and support future program design efforts and reported impact estimates.

The impact evaluation team ("the team") is made up of DNV GL, legacy Energy Resource Solutions (ERS), and GC Green Incorporated. The team achieved these objectives by reviewing program data, conducting phone surveys, and collecting operating parameters for the measures to support the evaluated gross savings estimates. The team estimated net savings based on responses from the HVAC market actors and end-use customers.

2.2 Evaluated measure groups

DNV GL reviewed and selected measure groups for this evaluation from the statewide list of HVAC ESPI uncertain measures. Our selection of measure groups was based primarily on each specific measure group's ESPI status, savings contributions to the HVAC portfolio in program year 2019, and whether there was a growth trend of the measure group in the HVAC market.

The HVAC measure groups selected in this evaluation were offered to end-users through various program delivery mechanisms including upstream, midstream, and downstream channels. The methodologies for evaluating these measure groups can vary by delivery mechanism and by how these measure groups influence the offering programs. The six measure groups chosen for this evaluation are:

- **Coil cleaning.** A condenser coil works best when outside air can be drawn easily through it. Cleaning the condenser coil helps ensure that heat is removed from the system efficiently.
- **Duct testing and sealing.** These measures involve testing and sealing residential ductworks to reduce leakage losses to specified levels.
- **Fan controls.** This is a retrofit add-on measure that increases the HVAC system's effectiveness by delaying fan motor shutdown at the conclusion of an air conditioning or heating cycle to extract the remaining cooling or heating potential. This measure is only applicable to older HVAC systems; newer systems already perform this function as a native feature.
- **Fan motor replacement.** These measures involve the replacement of existing permanent split-capacitor central supply (i.e., furnace, indoor, or air handler unit) fan motors with high-efficiency brushless fan motors in residential applications that use central air-cooled direct expansion cooling and/or furnace HVAC equipment.
- **Furnaces.** Manufacturers and distributors are offered incentives by the programs to stock and sell high-efficiency furnaces with the aim of reducing customers' final cost, thereby encouraging customers to purchase high-efficiency rather than standard-efficiency equipment. We evaluated programs delivering two furnace technologies: gravity wall furnaces and forced-air furnaces. Gravity wall furnaces are simple devices that rely on gravity and the tendency of warm air to rise and expand, rather than on fans and ducting, to distribute warmth throughout a space. They have the advantage of being inexpensive to buy, install, and maintain, but they are not as efficient at either combustion or warm-air distribution as forced-air furnaces. Gravity wall furnace measures were delivered via an upstream (manufacturer) program; forced-air furnace measures were delivered by both upstream (distributor) and downstream (end-user) programs.
- **Refrigerant charge adjustment (RCA).** These measures involve adjusting the amount of refrigerant within the air conditioning system. Over- or under-charged equipment operates less efficiently than properly charged systems, so adjusting the charge to manufacturer-specified amounts can save energy.

Table 2-1 lists the programs and claimed savings for these measure groups.

Table 2-1. Claimed savings of evaluated residential HVAC measure groups

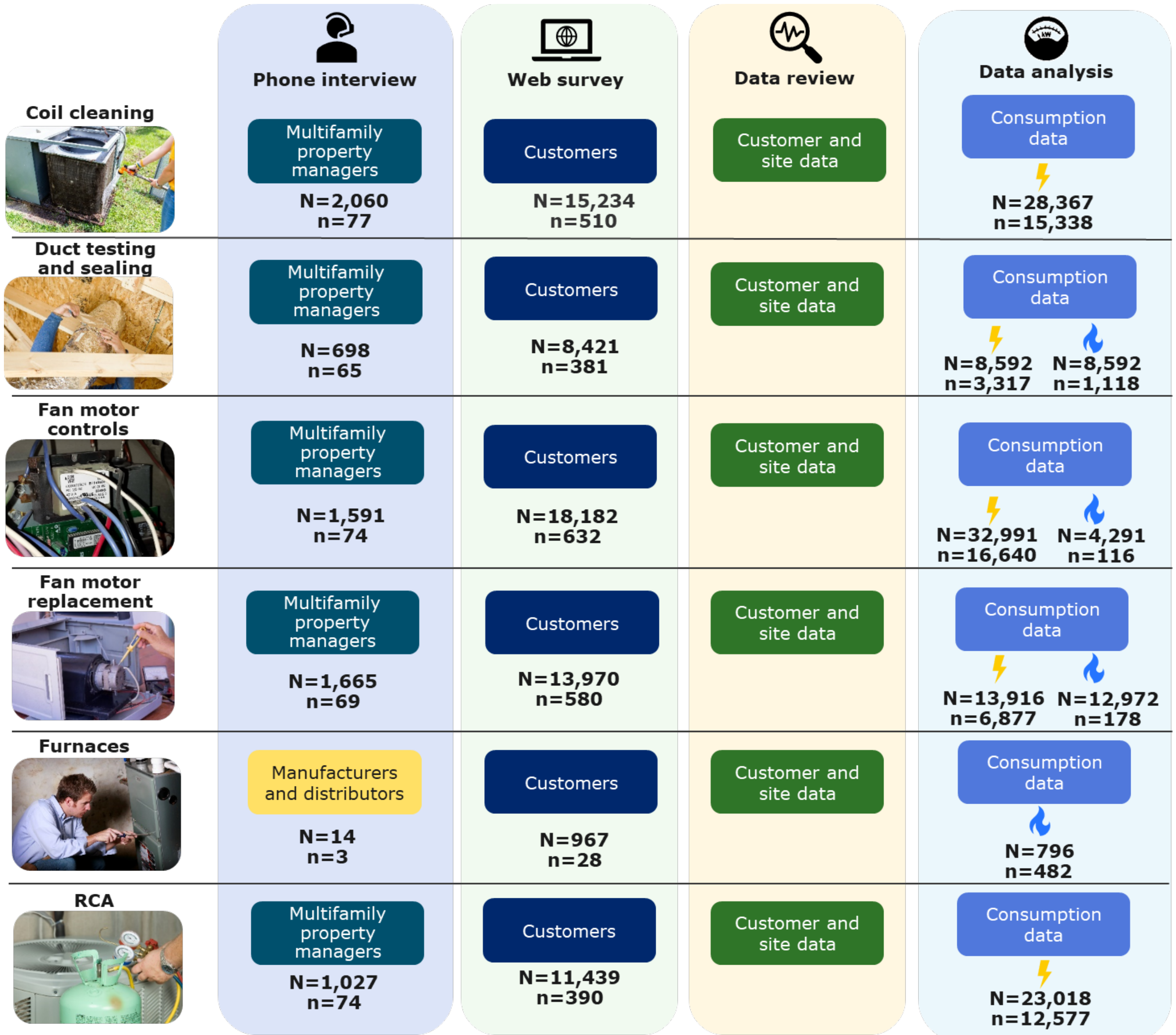
Measure Group	Program ID, Name	First Year Gross kW	First Year Gross kWh	Lifecycle Net kWh	First Year Gross Therm	Lifecycle Net Therm
Condenser Coil Cleaning	SDGE3279, 3P-Res-Comprehensive Manufactured-Mobile Home	81	74,890	186,608	-1	-3
	PGE21009, Direct Install for Manufactured and Mobile Homes	12	11,135	27,239	0	0
	PGE21008, Enhance Time Delay Relay	24	45,293	82,343	-10	-19
	SDGE3211, Local-CALS-Middle Income Direct Install (MIDI)	3	1,914	4,771	-1	-2
	PGE210011, Residential Energy Fitness program	198	174,324	316,657	-24	-44
	PGE21006, Residential HVAC	138	148,355	267,054	-15	-27
	SDGE3207, SW-CALS-MFEER	64	49,769	124,018	-6	-16
	Coil cleaning totals	**520**	**505,680**	**1,008,690**	**-57**	**-111**
Duct Testing and Sealing	SCE-13-TP-001, Comprehensive Manufactured Homes	613	425,993	1,097,215	18,731	48,466
	PGE21009, Direct Install for Manufactured and Mobile Homes	305	279,230	707,270	24,106	60,666
	SCG3820, RES-Direct Install Program	413	315,903	789,389	25,353	63,475
	SCE-13-SW-001G, Residential Direct Install Program	404	314,472	787,857	25,896	65,063
	PGE210011, Residential Energy Fitness program	2	1,370	3,411	260	648
	SCG3765, RES-Manufactured Mobile Home	1,159	841,954	2,147,453	56,300	144,298
	Duct testing and sealing totals	**2,896**	**2,178,922**	**5,532,595**	**150,646**	**382,616**
Fan Controls	SDGE3279, 3P-Res-Comprehensive Manufactured-Mobile Home	168	726,884	2,192,843	0	0
	SCE-13-TP-001, Comprehensive Manufactured Homes	415	1,155,041	4,161,162	0	0
	PGE21009, Direct Install for Manufactured and Mobile Homes	331	417,868	1,538,128	0	0
	PGE21008, Enhance Time Delay Relay	2	2,708	8,347	0	0
	SDGE3211, Local-CALS-Middle Income Direct Install (MIDI)	1	5,328	15,983	0	0
	SCE-13-SW-001G, Residential Direct Install Program	1,127	3,153,809	10,428,201	0	0
	PGE210011, Residential Energy Fitness program	979	1,391,827	4,215,739	0	0
	PGE21006, Residential HVAC	916	1,569,090	4,707,619	0	0
	SCG3702, RES-Residential Energy Efficiency Program	0	-4,955	-22,296	2,532	11,392
	SDGE3212, SW-CALS-Residential HVAC-QI/QM	16	59,981	179,944	0	0
	Fan controls totals	**3,955**	**8,477,581**	**27,425,670**	**2,532**	**11,392**
Fan Motor Replacement	SCE-13-TP-001, Comprehensive Manufactured Homes	654	789,838	2,687,146	0	0
	PGE21009, Direct Install for Manufactured and Mobile Homes	1,336	1,397,449	3,080,241	-10,057	-20,743
	PGE21008, Enhance Time Delay Relay	354	635,982	1,196,748	-4,702	-8,847
	SCE-13-SW-001G, Residential Direct Install Program	2,588	3,604,315	11,512,795	0	0
	PGE210011, Residential Energy Fitness program	1,146	1,293,193	2,353,087	-18,858	-34,194
	PGE21006, Residential HVAC	185	205,242	369,750	-3,206	-5,778
	SDGE3212, SW-CALS-Residential HVAC-QI/QM	1	597	5,374	0	0
	Fan motor replacement totals	**6,264**	**7,926,616**	**21,205,141**	**(36,823)**	**(69,562)**

Measure Group	Program ID, Name	First Year Gross kW	First Year Gross kWh	Lifecycle Net kWh	First Year Gross Therm	Lifecycle Net Therm
Furnaces	SCG3702, RES-Residential Energy Efficiency Program	0	0	0	23,996	287,957
	SCG3706, RES-Residential HVAC Upstream	0	0	0	171,689	2,060,264
	SDGE3302, SW-CALS - Residential HVAC Upstream	0	0	0	1,809	21,713
	Furnace totals	**0**	**0**	**0**	**197,494**	**2,369,934**
RCA	SDGE3279, 3P-Res-Comprehensive Manufactured-Mobile Home	503	474,311	1,182,237	-7	-17
	PGE21009, Direct Install for Manufactured and Mobile Homes	269	265,622	699,545	1	3
	PGE21008, Enhance Time Delay Relay	39	72,374	180,879	-17	-43
	SDGE3211, Local-CALS-Middle Income Direct Install (MIDI)	18	11,276	28,091	-4	-9
	PGE210011, Residential Energy Fitness program	523	451,108	1,124,753	-67	-167
	PGE21006, Residential HVAC	588	639,552	1,592,485	-60	-149
	SDGE3207, SW-CALS-MFEER	427	330,424	823,340	38	95
	Refrigerant charge adjustment totals	**2,367**	**2,244,667**	**5,631,330**	**(116)**	**(287)**
Residential HVAC PY2019 evaluation totals		**16,002**	**21,333,466**	**60,803,426**	**313,676**	**2,693,982**

2.3 Overview of approach

Figure 2-1 shows the evaluated measure groups selected for gross and net evaluation for the HVAC sector along with the data sources and activities used to evaluate these selected measure groups.

Figure 2-1. PY 2019 HVAC evaluated measure groups and study data sources



N=population; n=number of participants; the lightning bolt symbol=electric and the flame symbol=gas

We estimated gross savings at the household level using a normalized billing analysis that accounted for timing of measure installation, weather data, and advanced metering infrastructure (AMI) consumption data to estimate the gross impact of each measure group. We included non-participants as a comparison group in the analysis to isolate the measure group effects. We then used simulation results to disaggregate each household's savings into measure-level savings for that household. See Section 3 for more details.

For net savings estimates, we derived a NTGR by estimating the influence of various program activities had on manufacturer, distributor, and end-user behavior. By quantifying this influence, we were able to estimate the percent of the gross savings attributable to the programs and the percentage that was free-ridership.

Our team also administered web surveys to single-family and manufactured-home residents to ask about program awareness and the decision-making process to get participants thinking about those subjects, then ask how much the program affected the timing, efficiency, and quantity of the installed measure to develop net-to-gross estimate.

To calculate NTGR for the upstream furnace group and for multi-family occupants for the other five HVAC measures, we conducted phone surveys and confirmed with the program participant's customer decision maker the measure installation and other project details that support an estimate of free-ridership. The questions asked of interviewees were designed to gather information to allow the evaluation team to estimate participant free-ridership to support the development of net-to-gross and net savings values for this measure group.

2.4 Organization of report

Table 2-2 shows the overall organization of this report. Although overarching findings and recommendations are collected in Section 5, study findings and recommendations are included in Section 4 as well. Readers seeking a more comprehensive assessment of opportunities for program improvement are therefore encouraged to read these sections along with the appendices.

Table 2-2. Overall organizational structure of the report

Section	Title	Content
1	**Executive Summary**	Summary of results and high-level study findings
2	**Introduction**	Evaluation objectives, researchable issues, evaluation approach, and savings claims
3	**Study Methodology**	Sample design, measurement and verification (M&V) activities, gross impact determination, NTG survey
4	**Detailed Results**	Gross impacts and realization rates, measure and program differentiation, free ridership ratios and results, net realization rates, and NTG result drivers
5	**Conclusions**	Detailed gross and net findings, recommendations to improve program impacts
6	**Appendices**	IESR required reporting, billing analysis methodology, net-to-gross methodologies, surveys, detailed savings estimates, and draft report stakeholder comments and evaluator responses

3 METHODOLOGY

This section discusses the team's methods of conducting the evaluation for the primary tasks of this study including data sources, data collection techniques, sample design, gross impact, net impact, and constraints associated with the evaluation methodology.

The primary evaluation tasks were to estimate gross and net savings of the six selected incentivized HVAC residential measure groups across California.

Gross impacts of peak kW, kWh, and therm savings for the residential HVAC measures were determined through a combination of eQUEST energy simulation and analysis of AMI (advanced metering infrastructure) consumption data. A pre-/post-installation analysis of the program participants AMI consumption data with matched comparison non-participant control groups produced rigorous household-level savings estimates by building type and climate zone. Energy simulation models were developed for the three residential DEER building prototypes (single family, multifamily, and manufactured homes), across all building climate zones, and for all combinations of the evaluated measure groups.[4] These models were developed to estimate the expected household-level relative marginal impacts of each evaluated measure when they are installed in combination and at the same time by these programs. These simulation-based estimates were used to apportion the AMI-based household-level savings down to the evaluated measure-level savings.

To estimate net savings, we developed net-to-gross-ratios (NTGRs) for each measure group and then applied them to the evaluated gross savings estimates. We derived the NTGR by estimating the influence various program activities had on distributor and customer behavior. Program influence was determined for the upstream furnace programs by interviewing distributors; for all other delivery methods we surveyed end-use customers (residents or property managers, depending on property type). By quantifying this influence, we estimate what percentage of the gross savings was attributable to the programs and what portion was free-ridership.

3.1 Sample design

For our gross evaluation we used a curated census where we removed sites with missing or incomplete consumption data, sites with net metering or master metering, and so on.

For net savings, the web-based surveys and distributor interviews were census attempts, while the property manager telephone surveys relied on the sampling approach. For single-family homes we attempted a census approach and recruited participants for a web-based survey via bulk email. Because manufactured home and multi-family property managers are difficult to reach this way, we planned telephone surveys for this group. There were between 400 and 600 property managers for each of SCE, SCG, SDG&E, and about 2,000 for PG&E, so the team chose to develop a representative sample. For the property managers who had properties in both SCE and SCG service territories we sampled each PA separately. In addition to PA, we stratified the sample by savings. Table 3-1 presents the strata, the sample sizes, the population counts, and the proportion of the total multifamily population that fell within each stratum.

[4] The smart communicating thermostat measure was also modeled with the selected residential HVAC measures to support the analysis of these programs and their respective impact evaluation reports.

Table 3-1. Multifamily and manufactured home sample targets by PA

Strata	Target	Stratum Size	Percent of Population
PG&E-1	24	351	27.1
PG&E-2	24	59	4.6
PG&E-3	20	20	1.5
SCE-1	34	289	22.3
SCE-2	25	25	1.9
SCE-3	9	9	0.7
SCE-SCG-1	23	23	1.8
SCE-SCG-2	8	8	0.7
SDG&E-1	33	210	16.2
SDG&E-2	23	23	1.8
SDG&E-3	12	12	0.9
SCG-1	27	217	16.8
SCG -2	27	34	2.6
SCG -3	14	14	1.1
Total	**303**	**1294**	**100**

Table 3-2 presents the samples we achieved by strata. Out of a target of 303, we completed 266 surveys for the multifamily population.

Table 3-2. Multifamily and manufactured home sample targets achieved by PA

PA	Savings level	Surveys Completed	Stratum Population	Survey Weight
PG&E-1	1	38	351	9.24
PG&E-2	2	13	59	4.54
PG&E-3	3	3	20	6.67
SCE-1	1	59	289	4.9
SCE-2	2	13	25	1.92
SCE-3	3	4	9	2.25
SCE-SCG-1	1	4	23	5.75
SCE-SCG-2	2	3	8	2.67
SDG&E-1	1	44	210	4.77
SDG&E-2	2	6	23	3.83
SDG&E-3	3	4	12	3
SCG-1	1	49	217	4.43
SCG-2	2	18	34	1.89
SCG-3	3	8	14	1.75
Total		**266**	**1294**	

3.2 Data sources

Gross savings estimates for all residential HVAC measures were based on AMI consumption data (using hourly intervals for electricity and daily intervals for natural gas) provided by the PAs and eQUEST energy simulation results based on the best modeling inputs available from PA measure workpapers, previous HVAC evaluation data, and the most recent California Energy Commission Residential Appliance Saturation Study[5] (RASS). Because our net savings estimates were based on interviews and online surveys with appropriate parties, we requested contact information (name, street address, phone number, and email address) for residential customers, multi-family property managers, and manufacturers or distributors. Table 3-3 shows summary of data sources used to evaluate the measure groups.

Table 3-3. Summary of data sources and applicable measure groups

Data Sources	Description	Applicable Measure Group(s)
Program Tracking Data	IOU Program data includes number of records, savings per record, program type, name, measure groups, measure description, incentives etc.	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
Program Monthly Billing Data	PA billing data including kWh and therms	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
Program AMI Data	Hourly consumption data for electric PAs and daily consumption for gas PAs	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
Customer Data	PA supplementary information on both participating and non-participating customers	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
Weather Data	Hourly weather data for 73 National Oceanic and Atmospheric Administration weather stations across California	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
CZ2018 Typical Meteorological Year (TMY) Weather Data	TMY weather data based on historical weather observations	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA

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

Data Sources	Description	Applicable Measure Group(s)
Telephone/Web Surveys	Includes surveys of customers, distributors, other market actors, and PA program staff.	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
2019 California Residential Appliance Saturation Study (RASS)	Thermostat cooling and heating set-points	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
PA Workpapers	Simulation inputs	• Coil Cleaning • Duct Sealing • Fan Motor Controls • Fan Motor Replacement • Furnaces • RCA
Impact Evaluation of 2015 Commercial Quality Maintenance Programs (HVAC3)[6]	Simulation inputs	• RCA • Condenser coil cleaning
Laboratory HVAC Testing Research for 2013-14 (HVAC5)[7]	Simulation inputs	• RCA • Condenser coil cleaning

3.3 Data collection

Gross savings estimates were based entirely on energy simulation modeling and AMI consumption data; no additional primary data collection was necessary to assess gross savings. For our gross evaluation we used a curated census where we dropped sites with missing or incomplete consumption data, sites with net metering or master metering, and so on. Net savings estimates involved collecting responses from web surveys and telephone interviews. The data we collected for our analyses will be submitted to the CPUC for archiving following final release of this report.

3.4 Gross data analysis

For this evaluation we utilized energy consumption analysis and simulation modeling to estimate household-level and measure-level savings of the residential HVAC measure groups. Our analysis used at least 12 months of pre- and post-installation kWh and therms data. These energy consumption data were weather normalized so that we could use pre- and post-installation normalized annual consumption (NAC) to estimate savings for these measures. We used eQUEST

[6] Op. cit.
[7] Op. cit.

simulation modeling of the DEER residential prototypes to generate measure savings estimates that informed the disaggregation of meter-level savings to measure group savings.

The NAC basic rigor method as described in the 2006 California Energy Efficiency Evaluation Protocols (California Protocols) does not specify the use of a comparison group for aggregate program analysis; however, we used the recommended normalized metered energy consumption (NMEC) methods with a comparison group to control for underlying trends when conducting our consumption analysis. As a result, our consumption analysis approaches were of high rigor.

3.4.1 Applicable protocol

Applicable protocols for the proposed HVAC residential measures evaluation are described in the UMP Chapter 8 Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol.[8] The protocols provide guidance on quasi-experimental designs including two-stage methods and pooled fixed-effects modeling approaches. Furthermore, the site-level modeling part of the proposed approach is consistent with CalTrack methods that have been prescribed for pay-for-performance programs. These approaches are also consistent with California Protocol Enhanced rigor.

3.4.2 Impact methodologies

The evaluated residential HVAC measures were offered by 18 different residential energy efficiency programs across four PAs in PY2019. These programs delivered their measures using primarily downstream direct install delivery, although notably some furnace measures were incentivized through upstream manufacturer or distributor channels.

The disruptions to residential routines precipitated by the outbreak of COVID-19 resulted in a structural break in energy use in 2020, which is the post period for households that installed residential HVAC measures in PY2019. The primary focus of DNV GL's PY2019 evaluation is therefore on estimating HVAC measure savings among homes that installed these measures in PY2018 through direct install programs.

The PY2019 evaluation (which is based on installations of 2018 HVAC measures) provides a complete picture of residential HVAC measure savings per household available in different housing types and program delivery channels. Post periods cover 2018 and 2019 since energy use from this period was unaffected by COVID-19 disruptions.

Table 3-4 summarizes the groups and time periods involved in our PY2019 residential HVAC measures evaluation.

Table 3-4. Residential HVAC measure evaluation groups and periods in PY2019 evaluation

Participant Group	Installation Period	Comparison Group	Post Period
Multifamily Direct Install	2018	Future (PY2019) participants, matched comparison group	2019

[8] Agnew, K.; Goldberg, M. (2017). Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol, The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68564. http://www.nrel.gov/docs/fy17osti/68564.pdf

Participant Group	Installation Period	Comparison Group	Post Period
Manufactured Direct Install	2018	Future (PY2019) participants, matched comparison group	2019
All Residential Direct Install	2018	Future (PY2019) participants, matched comparison group	2019
Upstream Furnace	2018	Future (PY2019) participants, matched comparison group	2019

We analyzed consumption data to provide gross savings per unit separately for single family, multifamily, and manufactured homes by climate zone. Where a climate zone included claims from multiple Program Administrators (PAs), we combined all the claims to produce a single and consistent savings per household estimate for the climate zone. We extrapolated these results to any climate zone not robustly estimated directly in the consumption analysis, using methods similar to those that have been applied in the ex ante process.

We thoroughly assessed PA tracking data to select the homes included in the residential HVAC measures evaluation. A summary of our savings analysis plan is presented in Table 3-5 below.

Table 3-5. Summary of the residential HVAC measure savings analysis plan

Workplan Component	Included in the Analysis	Output
Consumption data analysis using data from direct install programs	Customers participating in PY2018 direct install programs that deliver multiple measures	Gross savings per household for direct install participants by climate zone, in the 2018/2019 post period
Gross savings extrapolation	Gross impacts for all PY2019 participants are estimated by applying results from PY2018 participants (extrapolating unit gross results from 2018 participants to the 2019 participants) to avoid interference from COVID-19 disruptions	Gross savings per residential HVAC measure by climate zone, in the 2018/2019 post period
Surveys with customers	• Samples of customers from each PY2019 program offering residential HVAC measures • Samples of matched non-participants used as comparators	• Verified installations PY2019 • NTGR by program PY2019 • Prevalence of residential HVAC measures among the comparison groups • Changes in household that impact energy use for all customers included in the billing analysis

3.4.3 Comparison groups

We conducted billing analysis using data from PY2018 participants on the assumption that gross savings per household is the same for both PY2018 and PY2019 participants within the same dwelling type, climate zone, and program delivery method. As indicated earlier, this decision was motivated by COVID-19 disruptions in energy use during most of 2020 (the "post" period for PY2019 participants) that made pre- to post-period energy use comparisons and analysis of program measure savings inappropriate.

Our billing analysis was based on a quasi-experimental design based on energy consumption data from PY2018 that compared participants to non-participants. The comparison group, used in the two-stage consumption data analysis, was taken from general population customers. This effort involved two phases. The first phase identified 10 households for every participant with similar energy use levels (based on monthly billing data) and trends (proxied by tenure[9]) within strata defined by characteristics such as dwelling type and geography. In the second phase, 1-to-1 matches were based on interval consumptions data to choose the optimal household from the initial 10 matches.

In all cases, matching models included annual energy use, the ratio of summer-to winter energy use to account for seasonality, tenure, and for electricity, 6 p.m. kWh for identified 'heat wave' periods used to capture peak demand conditions. 'Heat wave' periods were identified for each climate zone as weekdays between June through September where most customers had their maximum 6 p.m. kWh.

DNV GL used Mahalanobis distance matching without replacement for all matches used in the analysis. Future participants were selected based on matching with replacement because the number of non-participants available for matching was not always sufficiently large to allow matching without replacement.

Mahalanobis distance matching is scale-invariant and considers correlations of covariates to generate matches that are well-balanced. Balance is tested using standardized mean differences, the ratio of the variance of participant to matched comparison households, and visual inspection of the distribution of covariates of participants to matched comparison households.

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

3.4.4 eQUEST modeling to inform disaggregation of household-level savings

We estimated the impacts of simultaneously installed residential measures using energy simulations of residential DEER prototypes in eQUEST adjusted using the best data available from workpapers, studies, and previous evaluation findings. Table 3-6 lists the sources we used to adjust the eQUEST inputs. These estimates informed statistically-adjusted engineering (SAE) models, which we then used to disaggregate savings per household to the measure level as described in Appendix D. We

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

developed impact estimates by building type and climate zone for each of the residential HVAC measures under evaluation in PY2019. Applying eQUEST simulation results provided more realistic inputs to SAE models, which enables these models to simulate the effects of different measures more accurately.

Table 3-6. Sources for simulation inputs

Measure Group	Sources	Key eQUEST Modeling Parameters
Fan Controls	Deemed WP, WPSDGEREHC0024_R3_Res Fan Delay Controller, which is based on SCE17HC052, Rev 0 (a fan control study done by SCE). DNV GL recalculated savings using methodologies in the SCE study on 16 climate zone eQUEST prototype models, then calculated weighted average savings using tracking data claims (by climate zone)	Cooling EIR adjustment (efficient EIR = 0.87025 * baseline EIR)
Fan Motor Replacement	HVAC Year 2 (PY2018) evaluation - ex post simulation parameter for fan motor replacement measure group	Supply kW/flow adjustment (0.00065 to 0.0004 kW/cfm) Supply delta-T adjustment (2.054 F to 1.012 F)
Duct Testing and Sealing	Deemed WP, WPSDGEREHC1067 (cited DEER 2017 savings), SWSV001-01 (DEER2020 uses reduction from 40% to 12%, SF/MF only). WO32 (2010-12) and HVAC 6 (2013-14) provided robust residential post leakage data that indicates measured leakages are typically ~3% above target, so post leakage was increased by 3% over the workpaper claim.	Duct Air Loss % reduction (30.42% to 15% for SFM/MFM, 33.52% to 15% for DMO)
RCA	HVAC3 (2013-14) report and HVAC5 (2013-14) laboratory results (adjustment factors calculated from regression coefficient equation for each charge case) were used as reference for EIR adjustment factors for different charge scenarios (undercharged or overcharged, TXV or non-TXV) based on charge % level. Rather than simulating all variations such as mild undercharge, extreme undercharge, etc., in order to simplify the number of simulations tracking data was reviewed; 12% was a prominent undercharge and overcharge, as compared to 8% mentioned in workpaper. 12% was a reasonable compromise for a single undercharge/overcharge value, thus eliminating extraneous simulation runs. Tracking data claims for different variations of refrigerant charge were used to create a weighted average EIR adjustment factor of different RCA measure claims.	Cooling EIR adjustment (baseline EIR = efficient EIR x 1.0106976)
Coil Cleaning	HVAC3 (2013-14) report, table 12 Condenser coil cleaning DOE-2 adjustment factors	Cooling EIR adjustment (baseline EIR = efficient EIR x 1.065) Coil bypass factor adjustment (baseline BF = efficient BF * 0.99574)

Measure Group	Sources	Key eQUEST Modeling Parameters
Smart Communicating Thermostat	A customized set of baseline schedules and measure schedules are created and applied to eQUEST models for simulation. Baseline t-stat schedules are based on RASS data. After cleaning RASS data, at least 100 datapoints are used to create an average baseline t-stat schedule (heat + cool) for each climate zone (except for CZ1 and CZ5, neither of which had a statistically significant number of data points, so simulations for these CZs used the average of all other CZs). Measure t-stat schedules implemented an additional setback algorithm based on the existing setback of the baseline t-stat. T-stat setpoints/degrees of setback were then adjusted so that cooling and heating savings is 2% to 3%, in line with PA workpaper estimates.	Various heating and cooling setpoint schedules such that efficient schedule produces 2% to 3% cooling/heating savings when only setpoint schedule change is applied
Furnaces	WP SWHC031-01 Residential Furnace (forced-air units); WP SWHC001-01 Gravity Wall Furnace	Heating EIR (HIR) adjustment (equivalent baseline AFUE: 78, 80, 83; equivalent efficient AFUE: 93.5, 95.5, 96.5, 97.5. One efficient case is created using average results of the four efficient cases)

Once the best available simulation inputs were established, we modeled every combination of measures that occurred in the population. For instance, some households might have implemented duct sealing and testing, RCA, and fan control measures; others might have implemented only duct sealing and testing. Still others implemented other measure combinations. For each of these combinations we ran a "last-in" simulation to determine the marginal savings contribution of that measure to that combination.

For instance, using the first example (duct testing and sealing, RCA, and fan control measures) the process would be:

1. Run the simulation with duct testing and sealing and RCA.
2. Run it again with duct testing and sealing, RCA, and fan controls.
3. The difference between the two runs gives the savings for fan controls in the presence of duct testing and sealing and RCA, inherently accounting for interactions between measures in this measure combination.
4. Repeat the cycle, excluding then including duct testing and sealing, to get the duct testing and sealing savings contribution to this combination of measures.
5. Repeat the cycle, excluding then including RCA, to get the RCA savings contribution to this combination of measures.

We apportioned the estimated whole-home savings to measure savings in proportion to the engineering savings estimates for evaluated measures or tracking savings estimates for non-evaluated measures (lighting, smart power strips).

3.4.5 Load shapes

We also estimate demand savings that occur during pre- and post-program peak periods using hourly electric load data from participant and matched comparison homes. Peak periods are based on DEER defined heat wave periods of 3 consecutive non-holiday weekdays between June 1 and

September 30 with the hottest temperatures within the 9-hour window of 2 p.m. to 5 p.m.[10] This definition considers the average temperature, average afternoon temperature (12 p.m.–6 p.m.), and maximum temperature over the course of 3-day heatwave candidates. The peak period definition uses the most current TMY (typical meteorological year) datasets from the state's 16 Title 24 climate zones (CZs) so average demand impact is estimated under conditions that represent a grid peak.

We use 60-minute interval data during the hours of 2 p.m.–5 p.m. of the most common heat wave in the pre- and post-periods for both participant and comparison households to estimate whole-home peak demand reductions. We use the data in the following regression model to estimate average kW reductions:

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

Here:

$\Delta\overline{kW}_i$	=	Average pre-post demand difference for household i during the DEER-defined peak period
T_i	=	Treatment binary variable that takes the value of 1 if household i is in the treatment group and 0 if it is in the control
α, β	=	Model coefficients - β captures HER treatment effect on peak demand
ε_i	=	Model error term

We use estimated whole-home peak demand reductions from the above model with our estimates of whole-home and measure-specific energy (kWh) reductions to estimate demand (kW) reduction for each measure. We accomplish this by multiplying the ratio of whole-home peak demand to energy demand reductions with each measure's kWh savings.

3.4.6 Effective useful life (EUL)/remaining useful life (RUL)

The residential HVAC evaluation has used the ex-ante claimed EUL/RUL values for the evaluated measures. We will coordinate with the cross-cutting ex-ante and EUL deliverable teams to determine whether EUL/RUL update studies will be conducted.

3.5 Net savings

This section contains descriptions of how the evaluation team calculated net-to-gross ratios (NTGRs) for the six measure groups studied in this evaluation. In general, for each of the measure groups included in PY2019, used the same NTGR calculation methods as were used in PY2017 and PY2018 evaluations. Most of the measure groups have the same core approach with variation only in applicable free-ridership components. Upstream furnace group was the only exception, where DNV GL used a substantially different method. Table 3-7 provides a high-level summary of the methods used for each measure group. Detailed methodology used to calculate NTGRs for each is provided in Appendix F.

[10] DEER2008 version 2.05, adopted by CPUC Decision 09-09-047,3

Table 3-7. NTGR method summary

Measure Group	Net Savings Method
Coil cleaning	End-user self-report survey
Duct testing and sealing	
Fan motor controls	
Fan motor replacement	
Furnaces – downstream	
RCA	
Furnaces - upstream	Manufacturer/ distributor self-report survey

3.5.1 End-user survey approach

DNV GL surveyed program participants for the six evaluated HVAC measure groups. The primary survey objective was to develop attribution factors for estimating free-ridership. The survey data also provide information to identify and understand any trends observed in the results from factors outside the program.

Surveys were administered among participants via web browsers over approximately 10 weeks from November 2020 to January 2021. A sample frame for multifamily participant surveys was drawn from the set of matched comparison households used in the billing analysis used to estimate savings.

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

For furnaces, end-user surveys went to people who installed central gas furnaces. No gravity wall furnaces were included in the end-user survey sample due to lack of end-user contact information.

3.5.2 Upstream furnaces

For the upstream furnace measure group, DNV GL conducted in-depth interviews with manufacturers and distributors in addition to surveying end-users. These interviews gathered data needed to assess the causal pathway method of estimating attribution. This method of estimating attribution assesses how much the program affected distributors' stocking, upselling, and pricing behaviors (see Section 6.5 for details).

DNV GL received contact information for 19 distinct distributors from program staff. Of those 19, three distributed only gravity wall furnaces, and thus were duplicative with the gravity wall furnace manufacturer. Another two reported that they had no participation in the program. This reduced the eligible distributor population to 14. DNV GL completed interviews with a sample of three.

The vast majority of upstream furnaces were gravity wall furnaces. This type of furnace is produced by a single manufacturer in California. DNV GL completed an interview with the manufacturer. The manufacturer works directly with the PAs for the upstream furnace program and does not notify its distributors about the program or the rebates. Thus, there was only a single interview pertinent to gravity wall furnaces: the one with manufacturer itself.

The other two in-depth interviews were with central gas furnace distributors.

4 DETAILED RESULTS

This section presents the results of the gross and net evaluations of the measure groups. Gross impact realization rates (GRRs) and first-year evaluated gross and net savings are presented in this section by PA for electric energy (kWh), electric demand (kW), and gas energy (therms). Appendix B provides the Impact Evaluation Standard Reporting (IESR) high-level savings and standard per-unit savings. Appendix C provides the tabularized report recommendations. The evaluation used the PA-reported EUL measure values to calculate lifetime savings from first year savings.

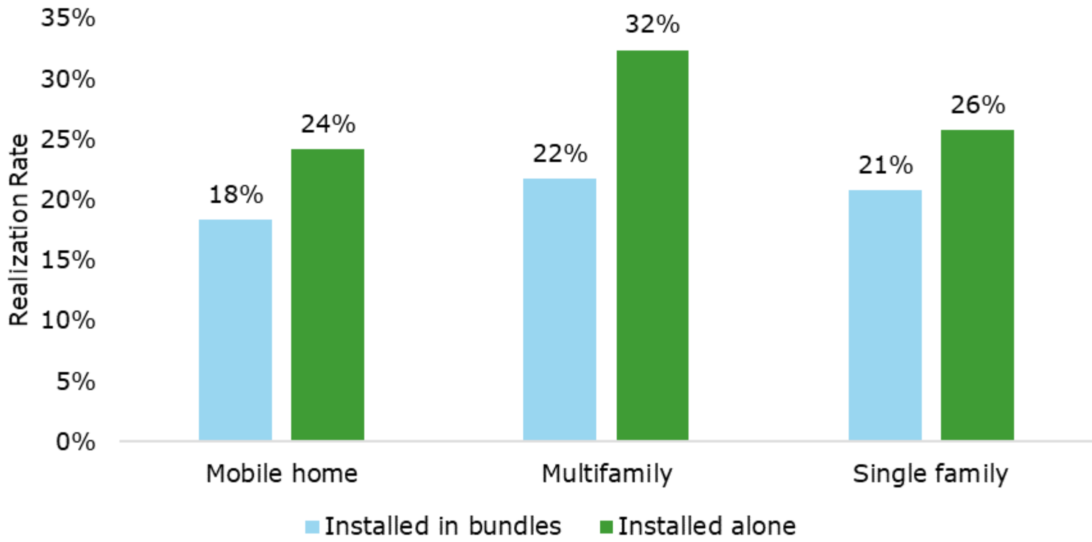
Gross savings at the household level were lower than expected. While this could be caused by one or more of the technologies not achieving the expected performance, it might also be attributable to the take-back (also known as rebound) effect. In simple terms the take-back effect is a reduction in the expected benefit from an efficiency improvement because the users respond to the reduced cost of operation by using more of the resource. Take-back could occur if the participants receiving these HVAC improvements change the way they use the equipment in response to these system efficiency gains in a way that improves their comfort without dramatically changing the costs of operating their system. For example, residents could be trading savings from efficiency improvements for greater comfort by raising the heating setpoints or lowering the cooling setpoints, knowing that their increased comfort won't increase their utility bills relative to the pre-existing conditions, before the installation of the energy efficiency measures. This rebound effect was confirmed by survey responses that show evidence of takeback: 57% of direct install participants report greater comfort post-installation compared to 48% of their matched non-participants.

For net savings, measure groups delivered via direct install mechanisms (coil cleaning, duct testing and sealing, fan controls, fan motor replacement, and RCA) have very high NTGRs. With some minor variations depending on the specific measures, survey respondents indicated that they installed the direct install measures because the utility offered them at reduced to no cost, because they were unaware the measure needed replacing, and because without the program the measure was not a high priority for them.

In contrast, the one upstream measure group, furnaces, had a less than 50% NTGR. For the furnace measure group, participants who installed them cited reasons such as improved comfort, reduction of energy bills, and reduced carbon emissions as common reasons for installing high-efficiency furnaces. These responses point to inherent motivation to choose higher-efficiency equipment, and thus helps explain the lower NTGRs for this measure.

In general, for measures with interactive effects / installed in bundles, realization rates are generally lower for measures installed in bundles compared to measures installed alone. Figure 4-1 illustrate this by building type.

Figure 4-1. Household savings realization rates for bundled measures vs. single measures



Appendix K presents the detailed savings estimate by building type and measure bundle for the climate zone with the highest number of households in the analysis by building type. These tables include bundles for which the study had 10 or more sampled households available for analysis.

4.1 Coil cleaning

4.1.1 Gross impact findings

The overall gross realization rates for the coil cleaning measure group across the PAs are 130% for kWh, 95% for peak kW and 0% for therms. The findings show more electrical energy savings were realized than the programs reported, while also finding no gas energy (therm) penalty for coil cleaning. These results align with previous evaluations' findings of this measure group. Our simulation analysis drew from the HVAC3 evaluation finding[11] of savings through improved cooling capacity and efficiency resulting from improved air flow and heat transfer across the coil.

Table 4-1 summarizes first-year gross and net savings for the coil cleaning measure group. Table 4-2 lists the population and sample sizes for coil cleaning and Table 4-3 shows the GRR, Relative Precision (RP), and p-value. The low p-value suggests that the difference in consumption between participants and matched non-participants did not occur by chance; in other words, the savings are due to coil cleaning activity.

[11] Ibid., table 12 Condenser coil cleaning DOE-2 adjustment factors

Table 4-1. First year savings summary - coil cleaning

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electric consumption (kWh)								
PGE	379,107	156%	592,386	61%	76%	452,583	231,097	196%
SDGE	126,573	51%	64,920	83%	100%	64,661	105,133	62%
Total	**505,680**	**130%**	**657,306**	**66%**	**79%**	**517,243**	**336,230**	**154%**
Peak electric demand (kW)								
PGE	372	118%	440	60%	75%	332	223	149%
SDGE	148	35%	52	83%	100%	51	123	42%
Total	**520**	**95%**	**492**	**67%**	**78%**	**383**	**346**	**111%**
Gas consumption (Therm)								
PGE	-49	0%	0	61%	80%	0	-30	0%
SDGE	-8	0%	0	87%	98%	0	-7	0%
Total	**-57**	**0%**	**0**	**65%**	**83%**	**0**	**-37**	**0%**

Table 4-2 Gross savings population and sample sizes - coil cleaning

PA	Population Size - electric	Completed Sample Size - electric
PGE	13,909	7,349
SCE	14,156	7,843
SDGE	302	146
Total	**28,367**	**15,338**

Note: Model counts are based on 2018 installations for PAs with 2019 claims for the measure

Table 4-3 Gross realization rates, relative precision, and p-values - coil cleaning

PA	kWh GRR	kWh Achieved RP[12]	kWh p-values	kW GRR	kW Achieved RP[13]	kW p-values	Therm GRR	Therm Achieved RP[14]	Therm p-values
PGE	156%	15%	0.00000	118%	15%	0.00000	-	-	-
SDGE	51%	39%	0.00003	35%	17%	0.00000	-	-	-
Total	**130%**	**15%**	**0.00000**	**95%**	**15%**	**0.00000**	-	-	-

[12] Relative precision at 90% confidence
[13] Relative precision at 90% confidence
[14] Relative precision at 90% confidence

4.1.2 Net impact findings

The NRRs for the coil cleaning measure group, which considers both the evaluated GRRs and NTGRs, are 154% for kWh, 111% for kW, and 0% for therms.

Table 4-4 presents the net results for condenser coil cleaning measure group. The statewide NTGR was 79% for kWh, 78% for kW, and 83% for therms. Overall, the evaluated NTGR was higher than the reported NTGR for all fuels and PAs except for SDGE's peak electric demand kW. This indicates that the program incentives offered to the end-users had a strong influence on improving uptake of coil cleaning measures.

High attribution scores for this measure were in part due to the proactive nature of direct install programs and the fact they offered free installation of the measures that people are not highly aware of. Verbatim answers of the single-family homeowners who received coil cleaning said the low/no cost measure was one of the key motivating factors (67%), and many (33%) indicated they were unaware of the need for coil cleaning. Likewise, 18% of respondents stated this measure came recommended from HVAC contractor recommendation as a way to reduce their energy bills. All these combined influenced the homeowner to install this measure. A handful of homeowners mentioned that other priorities (10%) or doubt about the energy savings from the measure (9%) were also common reasons among this group for not installing the measure in the absence of programs.

Table 4-4. First year net savings summary - coil cleaning[15]

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
PGE	61%	76%	452,583	231,097	196%
SDGE	83%	100%	64,661	105,133	62%
Total	**66%**	**79%**	**517,243**	**336,230**	**154%**
Peak Electric Demand (kW)					
PGE	60%	75%	332	223	149%
SDGE	83%	100%	51	123	42%
Total	**67%**	**78%**	**383**	**346**	**111%**
Gas Consumption (Therm)					
PGE	61%	80%	0	-30	0%
SDGE	87%	98%	0	-7	0%
Total	**65%**	**83%**	**0**	**-37**	**0%**

Table 4-5 presents the population size, completed sample size, and achieved relative precisions for the net savings assessments for the coil cleaning measure group. Confidence intervals are within 90/10 precisions for this measure group.

15 For all analyses DNV GL realization rates do not include the 5% market effects adder. NTGR values are calculated expanding DNV GL calculated ex-post gross to DNV GL calculated ex-post net values which do not include the 5% market effects adder. The only values that include the market effects 5% adder are the reported NTGR values in the tracking data; the tracking gross/net savings estimates themselves do not include the 5%. In order to address this in the reporting tables, the values for the "Reported NTGR" (which comes from the tracking data) have all been reduced by the 5% market effects adder so that the overall NRR are an equivalent comparison and thus not artificially deflating the results.

Table 4-5. Coil cleaning NTG population, sample, realization rate, and relative precision[16]

PA	Population Size	Sample Size	Evaluated kWh NTGR	kWh Achieved RP[17]	Evaluated kW NTGR	kW Achieved RP[18]	Evaluated Therm NTGR	Therms Achieved RP[19]
PGE	16,315	490	76%	4%	75%	4%	80%	3%
SDGE	979	97	100%	0%	100%	0%	98%	0%
Total	**17,924**	**587**	**79%**	**3%**	**78%**	**2%**	**83%**	**2%**

4.2 Duct testing and sealing

4.2.1 Gross impact findings

Table 4-6 presents the PY2019 statewide gross savings summary for the residential duct testing and sealing measure group. These results are lower than the PA-reported savings, but with a similar trend to PY2018 duct testing and sealing savings. evaluation results with substantial energy (kWh and therm) saving but low peak demand (kW) savings. The lower-than-reported results are caused by several factors. First, this year's sample considers participants claiming multiple interacting evaluated measures. In other words, other energy efficiency measures were installed at the same time as the duct testing and sealing measure where the measures have interactive effects[20] that affected the duct testing and sealing savings. Second Secondly, the overall evaluated household savings were lower than the PA-reported household savings and, since we estimated duct testing and sealing savings as a percentage of household savings, this measure resulted in lower evaluated savings than PY2018 results. Take-back could also be responsible for some of the reduction in achieved savings.

We based our simulation inputs on the workpaper WPSDGEREHC1067, modified by the findings of Work Order 32[21] and HVAC 6[22] studies. These studies showed that measured leakages are typically ~3% above target, so post leakage was increased by 3% over the workpaper claim.

Table 4-7 lists the population and sample sizes for duct testing and sealing; Table 4-8 shows the GRR, Relative Precision (RP), and p-value for this measure group. As with coil cleaning, the zero p-value indicates that the savings did not occur by chance but are due to the duct testing and sealing treatment.

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16 Relative precision at 90% confidence

17 Relative precision at 90% confidence

18 Relative precision at 90% confidence

19 Relative precision at 90% confidence

20 Interactive effects refer to the indirect effect on equipment energy usage due to installation of multiple energy efficient technologies. For example: The decline in heat emitted from high efficiency lighting technology may lead to an increase in heating usage and a decrease in cooling usage.

21 DNV GL, 2014, HVAC Impact Evaluation Final Report – WO32 HVAC – Vol.1, California Public Utilities Commission (CALMAC Study ID: CPU0100.01)

22 DNV GL, 2017, Final Report: 2014-16 HVAC Permit and Code Compliance Market Assessment (Work Order 6) Volume I – Report, California Public Utilities Commission (CALMAC Study ID: CPU0172.01

Table 4-6. First year savings summary - duct testing and sealing

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electric consumption (kWh)								
PGE	280,600	59%	164,588	84%	100%	164,402	236,893	69%
SCE	740,465	73%	540,020	85%	92%	497,174	628,357	79%
SCG	1,157,858	65%	748,148	85%	97%	723,269	978,947	74%
Total	**2,178,922**	**67%**	**1,452,756**	**85%**	**95%**	**1,384,845**	**1,844,197**	**75%**
Peak electric demand (kW)								
PGE	307	17%	53	83%	100%	53	255	21%
SCE	1,017	15%	149	85%	93%	139	867	16%
SCG	1,572	13%	206	85%	97%	199	1,331	15%
Total	**2,897**	**14%**	**408**	**85%**	**96%**	**390**	**2,453**	**16%**
Gas consumption (Therm)								
PGE	24,366	49%	12,029	84%	100%	12,005	20,438	59%
SCE	44,628	98%	43,891	85%	90%	39,416	37,843	104%
SCG	81,654	70%	56,992	85%	96%	54,492	69,258	79%
Total	**150,647**	**75%**	**112,912**	**85%**	**94%**	**105,913**	**127,539**	**83%**

Table 4-7. Gross savings population and sample sizes - duct testing and sealing

PA	Population Size - electric	Completed Sample Size - electric	Population Size - gas	Completed Sample Size - gas
PGE	1,405	519	1,405	521
SCE	4,635	2,678	4,635	-
SCG	2,123	-	2,123	539
SDGE	429	120	429	58
Total	**8,592**	**3,317**	**8,592**	**1,118**

Note: Model counts are based on 2018 installations for PAs with 2019 claims for the measure

Table 4-8. Gross realization rates, relative precision, and p-values - duct testing and sealing

PA	kWh GRR	kWh Achieved RP[23]	kWh p-values	kW GRR	kW Achieved RP[24]	kW p-values	Therm GRR	Therm Achieved RP[25]	Therm p-values
PGE	59%	28%	0.00000	17%	27%	0.00000	49%	94%	0.08063
SCE	73%	15%	0.00000	15%	14%	0.00000	98%	29%	0.00000
SCG	65%	15%	0.00000	13%	16%	0.00000	70%	29%	0.00000
Total	**67%**	**18%**	**0.00000**	**14%**	**17%**	**0.00000**	**75%**	**29%**	**0.00000**

23 Relative precision at 90% confidence

24 Relative precision at 90% confidence

25 Relative precision at 90% confidence

4.2.2 Net impact findings

The results of the web and phone surveys indicate the NTGRs for the duct testing and sealing measure group are 95% for kWh, 96% for kW, and 94% for therms. (Table 4-9) These evaluated NTGR values are higher than the PA reported values of 85% but are aligned with PY2018 evaluated NTGR values for the duct sealing and testing measure group. The resulting NRRs for the duct testing and sealing measure group, which considers both the evaluated GRRs and NTGRs, are 75% for kWh, 16% for kW, and 83% for therms.

Survey results suggest that the high NTGRs for this technology group are also due to the programs proactively delivering the technology to the end-users at reduced or no-cost via a direct install approach (70%). Pro-environmental reasons, such as "it's good for the environment," and "it could help with climate change," were uncommon (8%). In contrast to coil cleaning, a few respondents (6%) said they were unaware that the measure needed to be done.

Table 4-9. First year net savings summary - duct testing and sealing[26]

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption kWh					
PG&E	84%	100%	164,402	236,893	69%
SCE	85%	92%	497,174	628,357	79%
SCG	85%	97%	723,269	978,947	74%
Total	**85%**	**95%**	**1,384,845**	**1,844,197**	**75%**
Peak Electric Demand kW					
PG&E	83%	100%	53	255	21%
SCE	85%	93%	139	867	16%
SCG	85%	97%	199	1,331	15%
Total	**85%**	**96%**	**390**	**2,453**	**16%**
Gas Consumption (Therm)					
PG&E	84%	100%	12,005	20,438	59%
SCE	85%	90%	39,416	37,843	104%
SCG	85%	96%	54,492	69,258	79%
Total	**85%**	**94%**	**105,913**	**127,539**	**83%**

There was little variation in NTGRs among PAs or between fuels. Table 4-10 shows the population size, sample size, and kWh, kW, and therm NTGRs and relative precisions by PA and overall. Relative precisions were all very good. At the statewide level, relative precisions are 1% for all three fuels. This occurred because most participants reported high attribution. That both raised the NTGRs and decreased the variance.

[26] For all analyses DNV GL realization rates do not include the 5% market effects adder. NTGR values are calculated expanding DNV GL calculated ex-post gross to DNV GL calculated ex-post net values which do not include the 5% market effects adder. The only values that include the market effects 5% adder are the reported NTGR values in the tracking data; the tracking gross/net savings estimates themselves do not include the 5%. In order to address this in the reporting tables, the values for the "Reported NTGR" (which comes from the tracking data) have all been reduced by the 5% market effects adder so that the overall NRR are an equivalent comparison and thus not artificially deflating the results.

Table 4-10. Duct testing and sealing NTG estimate population, sample, realization rate, and relative precision[27]

PA	Population Size	Sample Size	Evaluated kWh NTGR	kWh Achieved RP[28]	Evaluated kW NTGR	kW Achieved RP[29]	Evaluated Therm NTGR	Therms Achieved RP[30]
PG&E	881	43	100%	0%	100%	0%	100%	0%
SCE	3,893	200	92%	2%	92%	2%	90%	2%
SCG	4,345	203	97%	1%	97%	1%	96%	1%
Total	**9,119**	**446**	**95%**	**1%**	**95%**	**1%**	**94%**	**1%**

4.3 Fan controls

4.3.1 Gross impact findings

Table 4-11 presents the PY2019 statewide savings summary by PA for the residential fan controls measures. Overall, the kWh, peak kW, and therms GRRs for this measure group are 19%, 13%, and 0%, respectively. The low electricity savings result from the competing effects of this measure and smart communicating thermostats, both of which are capable of delaying fan turn-off and were often reported to be installed together. 58% of fan controls were installed with a smart communicating thermostat. The analysis produced no appreciable gas savings for the heating focused SCG fan motor control measures. Table 4-13 lists the gross population, sample size, realization rates, and relative precisions for consumption, demand, and therms.

We based our simulation inputs on the workpaper WPSDGEREHC0024_R3_Res Fan Delay Controller. We calculated savings for all sixteen climate zones using eQUEST prototype models to which we applied methodologies in the SCE study, then calculated weighted average savings by climate zone using tracking data claims[31].

Table 4-12 lists the population and sample sizes for fan controls; Table 4-13 shows the GRR, RP, and p-value for this measure group. The low p-value for the electrical fuel type indicates a high confidence that there are electrical savings due to installation of fan controls. As mentioned above, we found no appreciable gas savings for this measure group.

27 Relative precision at 90% confidence

28 Relative precision at 90% confidence

29 Relative precision at 90% confidence

30 Relative precision at 90% confidence

31 For the SCG furnace-focused fan controller measures, the workpaper methodology could not be adapted for simulation modeling and ex ante savings estimates were applied to the analysis process as though they were the modeling output results.

Table 4-11. First year savings summary - fan controls

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electric consumption (kWh)								
PGE	3,381,492	23%	771,382	62%	85%	652,123	2,093,966	31%
SCE	4,308,849	16%	710,647	68%	89%	634,872	2,917,873	22%
SCG	-4,955	0%	0	90%	85%	0	-4,459	0%
SDGE	792,193	12%	97,714	60%	99%	96,978	477,754	20%
Total	**8,477,580**	**19%**	**1,579,743**	**65%**	**88%**	**1,383,974**	**5,485,134**	**25%**
Peak electric demand (kW)								
PGE	2,228	13%	284	60%	85%	243	1,337	18%
SCE	1,542	13%	202	69%	89%	180	1,061	17%
SCG	0	-	0	-	-	0	0	-
SDGE	184	15%	28	60%	99%	27	111	25%
Total	**3,955**	**13%**	**514**	**63%**	**88%**	**450**	**2,509**	**18%**
Gas consumption (Therm)								
PGE	0	-	0	-	-	0	0	-
SCE	0	-	0	-	-	0	0	-
SCG	2,532	0%	0	90%	90%	0	2,278	0%
SDGE	0	-	0	-	-	0	0	-
Total	**2,532**	**0%**	**0**	**90%**	**90%**	**0**	**2,278**	**0%**

Table 4-12. Gross savings population and sample sizes - fan controls

PA	Population Size - electric	Completed Sample Size - electric	Population Size - gas	Completed Sample Size - gas
PGE	11,921	6,338	-	-
SCE	20,127	9,942	-	-
SCG	-	-	4,291	116
SDGE	943	360	-	-
Total	**32,991**	**16,640**	**4,291**	**116**

Note: For SCG, results reflect HVAC furnace fan control installations

Table 4-13. Gross realization rates, relative precision, and p-values - fan controls

PA	kWh GRR	kWh Achieved RP[32]	kWh GRR p-values	kW GRR	kW Achieved RP[33]	kW GRR p-values	Therm GRR	Therm Achieved RP[34]	Therm GRR p-values
PGE	23%	14%	0.00000	13%	13%	0.00000	-	-	-
SCE	16%	15%	0.00000	13%	14%	0.00000	-	-	-
SCG	0%	-	-	0%	-	-	0%	>100%	0.97912
SDGE	12%	41%	0.00006	15%	24%	0.00000	-	-	-
Total	**19%**	**14%**	**0.00000**	**13%**	**13%**	**0.00000**	**0%**	**>100%**	**0.97912**

4.3.2 Net impact findings

Table 4-14 provides the NTG results by PA for the HVAC fan controls measures. The overall NTGRs were 88% for kWh and for kW. No evaluated therm NTGRs were available for the state due to a lack of survey responses by SCG fan controls recipients and therefore the reported SCG therm NTGR is passed through. No net therm savings were realized for this measure group. As with the other direct install measures in this evaluation, the program's overall high attribution can be explained through the proactive and low/no cost approach. Most (61%) respondents selected the utility offering measure being low cost or no cost to consumer / offered via discount or rebate as a reason for installing the measure. Many (21%) cited the HVAC contractor recommended installing the measure to reduce their energy bills.

The patterns of reasons for installation among respondents helps validate the attribution scores. Respondents who opted into the service for reasons pertaining to incentives also stated that they would not have completed these projects without the program due to reasons such as uncertainty if energy savings would be worth the cost or was too expensive otherwise (10%), was not a priority to replace (7%), were unaware measure needed to be replaced (5%).

Despite generally high NTGRs, evaluated net savings were low which is due to lower evaluated gross savings for this measure group. This resulted in NRRs at or below 31%.

Table 4-14. First year net savings summary - fan controls[35]

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
PGE	62%	85%	652,123	2,093,966	31%
SCE	68%	89%	634,872	2,917,873	22%

[32] Relative precision at 90% confidence

[33] Relative precision at 90% confidence

[34] Relative precision at 90% confidence

[35] For all analyses DNV GL realization rates do not include the 5% market effects adder. DNV GL NTGR values are calculated expanding DNV GL calculated ex-post gross to DNV GL calculated ex-post net values which do not include the 5% market effects adder. The only values that include the market effects 5% adder are the reported NTGR values in the tracking data; the tracking gross/net savings estimates themselves do not include the 5%. In order to address this in the reporting tables, the values for the "Reported NTGR" (which comes from the tracking data) have all been reduced by the 5% market effects adder so that the overall NRR are an equivalent comparison and thus not artificially deflating the results.

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
SCG	90%	90%	0	-4,459	0%
SDGE	60%	99%	96,978	477,754	20%
Total	**65%**	**88%**	**1,383,974**	**5,485,134**	**25%**
Peak Electric Demand (kW)					
PGE	60%	85%	243	1,337	18%
SCE	69%	89%	180	1,061	17%
SCG	85%	85%	0	0	0%
SDGE	60%	99%	27	111	25%
Total	**63%**	**88%**	**450**	**2,509**	**18%**
Gas Consumption (Therm)					
PGE	-	-	-	-	-
SCE	-	-	-	-	-
SCG	90%	85%	0	2,278	0%
SDGE	-	-	-	-	-
Total	**90%**	**85%**	**0**	**2,278**	**0%**

There was little variation in NTGRs among PAs or between fuels. Table 4-15 shows the population size, sample size, and kWh, kW, and therm NTGRs and relative precisions by PA and overall. Relative precisions are 2% at the statewide level for both kWh and kW. The low relative precisions area a result of most participants reporting high attribution, which both raised the NTGRs and produced a low variance in the results.

Table 4-15. Fan controls NTG population, sample, realization rate, and relative precision[36]

PA	Population Size	Sample Size	Evaluated kWh NTGR	kWh Achieved RP[37]	Evaluated kW NTGR	kW Achieved RP[38]	Evaluated Therm NTGR	Therms Achieved RP[39]
PG&E	9,612	247	85%	4%	85%	3%	-	-
SCE	8,369	382	89%	2%	89%	2%	-	-
SCG	661	0	85%	-	-	-	85%	-
SDG&E	1,181	77	99%	0%	99%	0%	-	-
Total	**19,773**	**706**	**88%**	**2%**	**88%**	**2%**	**85%**	**-**

[36] Relative precision at 90% confidence
[37] Relative precision at 90% confidence
[38] Relative precision at 90% confidence
[39] Relative precision at 90% confidence

4.4 Fan motor replacement

4.4.1 Gross impact findings

Table 4-16 presents the PY2019 statewide savings summary for the residential fan motor replacement measure group. Overall, the kWh, peak kW, and therms GRRs for this technology are 27%, 17%, and 29%, respectively. This means both the evaluated energy and demand savings are substantially lower than the PA-reported savings. This is due to the consideration of interactive effects among the multiple measures installed and because the analysis showed that lower savings are realized at the household level than the sum of expected saving for the measures installed at the household level. In other words, when multiple energy efficiency measures are installed in a home at the same time affecting the same energy system(s), the savings from the combination of measures is often different from, and usually less than, the sum of the savings that would result from installing each measure alone. For example, savings from the combination of high-efficiency electrical equipment, building shell improvements, and building controls is typically less than the sum of the savings from installing each of these without the others.

Table 4-17 lists the population and sample sizes for fan motor replacement.

Table 4-18 shows the GRR, RP, and p-value for this measure group. The low p-value for the electrical fuel type indicates a high confidence that there are electrical savings due to replacement of fan motors. The high p-value for therms suggests that at least some of the difference in natural gas consumption between participants and matched non-participants may have occurred by chance and so may not result from fan motor replacement.

Table 4-16. First year savings summary - fan motor replacement

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electric consumption (kWh)								
PGE	3,531,866	29%	1,036,292	66%	94%	971,110	2,333,275	42%
SCE	4,394,153	25%	1,105,867	68%	87%	958,898	2,982,770	32%
SDGE	597	35%	210	60%	100%	210	358	59%
Total	**7,926,616**	**27%**	**2,142,370**	**67%**	**90%**	**1,930,217**	**5,316,403**	**36%**
Peak electric demand (kW)								
PGE	3,021	24%	725	60%	93%	677	1,813	37%
SCE	3,241	11%	342	69%	87%	298	2,237	13%
SDGE	1	8%	0.1	60%	100%	0	0	18%
Total	**6,263**	**17%**	**1,067**	**65%**	**91%**	**975**	**4,050**	**24%**
Gas consumption (Therm)								
PGE	-36,823	29%	-10,760	63%	91%	-9,802	-23,187	42%
SCE	0	-	0	-	-		-	-
SDGE	0	-	0	-	-		-	-
Total	**-36,823**	**29%**	**-10,760**	**63%**	**91%**	**-9,802**	**-23,187**	**42%**

Table 4-17. Gross savings population and sample sizes - fan motor replacement

PA	Population Size - electric	Completed Sample Size - electric	Population Size - gas	Completed Sample Size - gas
PGE	11,224	5,436	11,224	178
SCE	2,488	1,377	1,748	-
SCG	0	-	0	0
SDGE	204	64	0	0
Total	**13,916**	**6,877**	**12,972**	**178**

Note: Model counts are based on 2018 installations for PAs with 2019 claims for the measure

Table 4-18. Gross realization rates, relative precision, and p-values - fan motor replacement

PA	kWh GRR	kWh Achieved RP[40]	kWh GRR p-values	kW GRR	kW Achieved RP[41]	kW GRR p-values	Therm GRR	Therm Achieved RP[42]	Therm GRR p-values
PGE	29%	13%	0.00000	24%	23%	0.00000	29%	>100%	0.72822
SCE	25%	13%	0.00000	11%	12%	0.00000	-		
SDGE	35%	14%	0.00750	8%	14%	0.00000	-		
Total	**27%**	**12%**	**0.00000**	**17%**	**17%**	**0.00000**	**29%**	**>100%**	**0.72822**

4.4.2 Net impact findings

The NTGRs for fan motor replacement kWh, kW, and therms were 90%, 91%, and 91% respectively. There were slight variations in NTGRs across PAs and fuels. Table 4-19 shows the overall net savings results for both PAs and statewide including reported NTGR, evaluated NTGR, reported net savings, evaluated net savings, and net realization rates.

Despite high NTGRs, NRRs were below 50% due to lower evaluated gross savings. This resulted in NRRs below 60%.

Table 4-19. First year net savings summary - fan motor replacement[43]

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
PGE	66%	94%	971,110	2,333,275	42%
SCE	68%	87%	958,898	2,982,770	32%
SDGE	60%	100%	210	358	59%
Total	**67%**	**90%**	**1,930,217**	**5,316,403**	**36%**

40 Relative precision at 90% confidence

41 Relative precision at 90% confidence

42 Relative precision at 90% confidence

43 For all analyses DNV GL realization rates do not include the 5% market effects adder. NTGR values are calculated expanding DNV GL calculated ex-post gross to DNV GL calculated ex-post net values which do not include the 5% market effects adder. The only values that include the market effects 5% adder are the reported NTGR values in the tracking data; the tracking gross/net savings estimates themselves do not include the 5%. In order to address this in the reporting tables, the values for the "Reported NTGR" (which comes from the tracking data) have all been reduced by the 5% market effects adder so that the overall NRR are an equivalent comparison and thus not artificially deflating the results.

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
Peak Electric Demand (kW)					
PGE	60%	93%	677	1,813	37%
SCE	69%	87%	298	2,237	13%
SDGE	60%	100%	0	0	18%
Total	**65%**	**91%**	**975**	**4,050**	**24%**
Gas Consumption (Therm)					
PGE	63%	91%	-9,802	-23,187	42%
SCE	-	-	-	-	-
SDGE	-	-	-	-	-
Total	**63%**	**91%**	**-9,802**	**-23,187**	**42%**

Similar to the other direct install measures in this evaluation, the program's overall high attribution can be explained through the proactive and low/no cost approach. Most (57%) respondents selected the utility offering measure being low cost or no cost to consumer / offered via discount or rebate as a reason for installing the measure. Many (26%) cited the HVAC contractor recommended installing the measure. As with coil cleaning, many (23%) respondents were unaware the measure needed to be done. Our net surveys revealed that a high number of program participants needed the program incentive to upgrade their fan motors, and most of residential end-users also said they wouldn't have known to install the high-efficiency fan motor without program outreach.

Table 4-20 presents the completed sample size and achieved relative precisions for the net savings assessments for the fan motor replacement measure group. Electricity-related relative precisions were each 1% at the statewide level. At 9%, relative precision was not quite as good for Therms. However, it still met the 90/10 threshold. The low relative precisions occurred because most participants reported high attribution. That both raised the NTGRs and decreased the variance.

Table 4-20. Fan motor replacement NTG population, sample, realization rate, and relative precision[44]

PA	Population Size	Sample Size	Evaluated kWh NTGR	kWh Achieved RP[45]	Evaluated kW NTGR	kW Achieved RP[46]	Evaluated Therm NTGR	Therms Achieved RP[47]
PGE	6,994	266	94%	1%	93%	1%	91%	14%
SCE	8,640	382	87%	2%	87%	2%	-	-
SDGE	1	1	100%	0%	100%	0%	-	-
Total	**15,635**	**649**	**90%**	**1%**	**91%**	**1%**	**91%**	**14%**

44 Relative precision at 90% confidence

45 Relative precision at 90% confidence

46 Relative precision at 90% confidence

47 Relative precision at 90% confidence

4.5 Furnaces

For upstream furnace programs, furnace manufacturers and distributors are offered incentives by the PAs to stock and sell high-efficiency furnaces with the aim of reducing customers' final cost, thereby encouraging customers to purchase high-efficiency rather than standard-efficiency equipment. SCG and SDG&E both offer upstream programs. SCG also provides a downstream program delivery, providing incentives directly to the purchaser. Table 4-16 presents the PY2019 statewide savings summary for the residential furnace measure group. Overall, the therms GRR for this technology is 14%.

Table 4-21. First year savings summary - furnaces

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Gas consumption (Therm)								
SCG	195,685	14%	26,667	60%	27%	7,200	117,411	6%
SDGE	1,809	45%	811	60%	55%	446	1,086	41%
Total	**197,494**	**14%**	**27,479**	**60%**	**28%**	**7,646**	**118,497**	**6%**

All of SDGE's savings were from central air furnaces. In contrast, 91% of SCG's claims (72% of savings) were from gravity wall furnaces. Thus, the PA split is also representative of the technology split. Because the majority of claims were from gravity wall furnaces (through SCE only), those findings dominate the overall results.

4.5.1 Gross impact findings

SDG&E and SCG are the two PAs who offered this measure group. Overall, the therms GRR for this measure group was 14%. This result is driven partly by the outcome of the analysis of high efficiency central furnaces only realizing slightly less than half of their reported savings and partly by the evaluation team's assigning a GRR of 0% for the gravity wall furnace measures due to inadequate program design and lack of installation documentation that precludes analysis of these furnaces. Out of 21,919 total furnace claims, 19,752 were gravity wall furnace claims. For these gravity wall furnace claims, there was no information available for the evaluation team to verify the installation of these furnaces.

Our savings simulation inputs for forced-air furnaces were taken without modification from SWHC031-01, Residential Furnaces (forced-air units). Table 4-22 lists the population and sample sizes for the furnace measure group; Table 4-23 shows the GRR, RP, and p-values. The low p-value shows a high confidence that our savings estimates result from furnace replacements rather than by chance.

Table 4-22. Gross savings population and sample sizes - furnaces

PA	Population Size - gas	Completed Sample Size - gas
PGE	97	56
SCE	0	-
SCG	665	398
SDGE	34	28

PA	Population Size - gas	Completed Sample Size - gas
Total	**796**	**482**

Note: Model counts are based on 2018 installations for PAs with 2019 claims for the measure

Table 4-23. Gross realization rates, relative precision, and p-values - furnaces

PA	Therm GRR	Therm Achieved RP[48]	Therm GRR p-values
SCG	14%	33%	0.00000
SDGE	45%	52%	0.00196
Total	**14%**	**37%**	**0.00000**

4.5.2 Net impact findings

Table 4-24 presents the net results for furnaces. The analysis of the web and phone surveys indicate the NTGRs for the residential furnace technology group is 28% for therms. This evaluated NTGR is significantly lower than the PA-reported NTGR of 60%. The low evaluated NTGR for the furnace technology, relative to the other groups studied in this report, is not surprising because unlike those technologies, the furnaces are delivered as replacements for broken equipment rather than as optional add-ons or maintenance services, furnaces are well known to customer decision makers, and furnaces are high-cost durable goods where the programs incentivize only marginal efficiency improvement and not most or all of the cost of the technology. Surveys revealed that a high number of participants would have installed the same efficient furnace without the program incentive.

The net realization rates for the technology group, which considers both the evaluated GRRs and NTGRs, is 6% for therms.

Table 4-24. First year net savings summary - furnaces

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Gas Consumption (Therm)					
SCG	60%	27%	7,200	117,411	5%
SDGE	60%	55%	446	1,086	41%
Total	**60%**	**28%**	**7,646**	**118,497**	**6%**

DNV GL completed one in-depth interview pertinent to gas-fired gravity wall furnaces delivered through an upstream program. This interview was with the sole manufacturer of the equipment incentivized through the SCG program. The manufacturer reported that the program increased their stocking of high efficiency gravity wall furnaces by 42%. The program had no effect on its upselling

[48] Relative precision at 90% confidence

practices, and the manufacturer did not answer the question on pricing. The manufacturer also indicated a 20% increase in sales of high efficiency gravity wall furnaces as a result of the program. Using a preponderance of evidence approach, DNV GL considered the answer to the sales increase to be the most applicable answer for purposes of establishing program attribution. Thus, DNV GL assigned the program an NTGR of 20% for gravity wall furnaces delivered through this upstream channel.

DNV GL completed interviews with two distributors who provided information pertinent to central gas-fired forced air furnaces delivered through an upstream program. Those two distributors reported that the program had no effect on either their stocking or their upselling practices. One distributor said they pass through all of the rebates, and the other said they only pass through downstream rebates. This led DNV GL to conclude that the distributors did not fully understand the rebate passthrough question. The distributors indicated that the program increased their sales of high efficiency forced air furnaces by 30% (±40). Secondary results from the interviews indicated that the distributors experienced no change to sales of high efficiency furnaces attributable to the program. Based on the results of the distributor surveys, DNV GL applied an evaluated NTGR of 30% to the upstream central furnace claims.

The analysis of survey responses of downstream program central furnace measure participants produces an NTGR of 24% for SCG therm savings, while SDG&E has a passed-through therm NTGR of 55% due to a lack of adequate survey responses. There were only four SDG&E respondents and they all indicated full free-ridership among all questions pertaining to program attribution.

Typically, furnaces are replaced on end of useful life and are measures that a home will not go without. The primary decision that the program can affect is efficiency, and the participants surveyed for PY2019 indicated they often would have installed the same efficiency as they did if the program did not exist. No other open-ended survey responses provide additional insight into participant decision making around furnaces. The downstream NTGR results are similar to other downstream residential measures DNV GL has evaluated for PY2018 and PY2019, such as smart thermostats.

Table 4-25 presents the overall furnace net results and precision estimates for therm savings. Overall, the evaluation achieved 21% relative precision for therms. Relative precisions for furnaces did not meet the 90/10 threshold. There were two main causes: small samples and low NTGRs.

Table 4-25. Furnaces NTG population, sample, realization rate, and relative precision[49]

PA	Population Size	Sample Size	Evaluated Therm NTGR	Therms Achieved RP[50]
SCG	895	27	27%	44%
SDGE	86	4	55%	0%
Total	**981**	**31**	**28%**	**21%**

[49] Relative precision at 90% confidence

[50] Relative precision at 90% confidence

4.6 Refrigerant charge adjustment

4.6.1 Gross impact findings

The low realization rate is a result of two drivers: the impacts of RCA as modeled are the smallest of any of the measure groups evaluated and second, total evaluated household savings are smaller than the sum of reported savings. Even though our simulations assumed that the typical system is 12% undercharged (based on studies HVAC3[51] and HVAC5[52]) rather than the 8% assumed by PA workpapers, the savings are much lower than reported. Table 4-26 shows the first-year gross savings by PA. (As with all of the residential HVAC measures evaluated in this cycle, household-level savings were much lower than expected and measure savings cannot exceed the household's total savings.)

Simulation inputs for RCA were derived from HVAC3[53] field results and HVAC5[54] laboratory findings. Rather than simulating all variations (e.g. mild undercharge with TXV, extreme undercharge without TXV), we reviewed the prevalence of the reported variations; 12% was a prominent undercharge and overcharge, as compared to the 8% mentioned in workpaper. Settling on 12% for a single undercharge/overcharge value eliminated the complexity that would ensue from simulation runs for each measure code's assumptions. In addition, tracking data claims for different variations of refrigerant charge were used to create a weighted average EIR adjustment factor of different RCA measure claims.

Table 4-27 lists the RCA population and sample sizes; Table 4-28 shows the GRR, RP, and p-values. The low p-values indicate a high confidence that there are electrical savings between participants and matched non-participants resulting from refrigerant charge adjustments rather than by chance.

Table 4-26. First year savings summary - RCA

PA	Reported Gross Savings	GRR	Evaluated Gross Savings	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electric consumption (kWh)								
PGE	1,428,656	5%	77,945	84%	81%	62,960	1,199,221	5%
SDGE	816,010	2%	16,310	83%	100%	16,268	677,889	2%
Total	**2,244,666**	**4%**	**94,255**	**84%**	**84%**	**79,228**	**1,877,110**	**4%**
Peak electric demand (kW)								
PGE	1,419	3%	38	83%	81%	31	1,178	3%
SDGE	947	1%	9	83%	100%	9	787	1%
Total	**2,366**	**2%**	**47**	**83%**	**84%**	**40**	**1,965**	**2%**
Gas consumption (Therm)								
PGE	-143	0%	0	83%	81%	0	-119	0%
SDGE	28	0%	0	83%	98%	0	23	0%
Total	**-115**	**0%**	**0**	**83%**	**84%**	**0**	**-96**	**0%**

[51] Op. cit.
[52] Op. cit.
[53] Op. cit.
[54] Op. cit.

Table 4-27. Gross savings population and sample sizes - RCA

PA	Population Size	Completed Sample Size
PGE	7,903	4,376
SCE	14,286	7,925
SDGE	829	276
Total	**23,018**	**12,577**

Note: Model counts are based on 2018 installations for PAs with 2019 claims for the measure

Table 4-28. Gross realization rates, relative precision, and p-values - RCA

PA	kWh GRR	kWh Achieved RP[55]	kWh GRR p-values	kW GRR	kW Achieved RP[56]	kW GRR p-values
PGE	5%	30%	0.00000	3%	15%	0.00000
SDGE	2%	59%	0.00593	1%	25%	0.00000
Total	**4%**	**22%**	**0.00000**	**2%**	**15%**	**0.00000**

4.6.2 Net impact findings

Table 4-29 presents the net results for the HVAC RCA measure group. Overall, the evaluated NTGR was higher than the reported NTGR which shows the program has strong influence on the measure. The overall NTGR for kWh, kW, and therms was 84%.

Table 4-29. First year net savings summary - RCA[57]

PA	Reported NTGR	Evaluated NTGR	Evaluated Net Savings	Reported Net Savings	NRR
Electricity consumption (kWh)					
PGE	84%	81%	62,960	1,199,221	5%
SDGE	83%	100%	16,268	677,889	2%
Total	**84%**	**84%**	**79,228**	**1,877,110**	**4%**
Peak Electric Demand (kW)					
PGE	83%	81%	31	1,178	3%
SDGE	83%	100%	9	787	1%
Total	**83%**	**84%**	**40**	**1,965**	**2%**
Gas Consumption (Therm)					
PGE	83%	81%	0	-119	0%
SDGE	83%	98%	0	23	0%
Total	**83%**	**84%**	**0**	**-96**	**0%**

55 Relative precision at 90% confidence

56 Relative precision at 90% confidence

57 For all analyses DNV GL realization rates do not include the 5% market effects adder. NTGR values are calculated expanding DNV GL calculated ex-post gross to DNV GL calculated ex-post net values which do not include the 5% market effects adder. The only values that include the market effects 5% adder are the reported NTGR values in the tracking data; the tracking gross/net savings estimates themselves do not include the 5%. In order to address this in the reporting tables, the values for the "Reported NTGR" (which comes from the tracking data) have all been reduced by the 5% market effects adder so that the overall NRR are an equivalent comparison and thus not artificially deflating the results.

Similar to the other direct install measures in this evaluation, the programs' overall high attribution rates can be explained through the proactive and low/no cost approach. Most (67%) respondents selected the utility offering measure being low cost or no cost to consumer / offered via discount or rebate as a reason for installing the measure. Many (17%) cited the HVAC contractor recommended installing the measure. Similar to coil cleaning, many (30%) respondents were unaware the measure needed to be done.

Table 4-30 presents the completed sample size and achieved relative precisions for the net savings assessments for the fan motor replacement measure group. Overall, the evaluation achieved 2% relative precision for kWh, 2% RP for kW, and 3% relative precision for therms. The low relative precision values occurred because most participants reported high attribution. That both raised the NTGRs and decreased the variance.

Table 4-30. RCA NTG population, sample, realization rate, and relative precision[58]

PA	Population Size	Sample Size	Evaluated kWh NTGR	kWh Achieved RP[59]	Evaluated kW NTGR	kW Achieved RP[60]	Evaluated Therm NTGR	Therms Achieved RP[61]
PGE	11,578	369	81%	4%	81%	3%	81%	3%
SDGE	888	95	100%	0%	100%	0%	98%	1%
Total	**12,466**	**464**	**84%**	**2%**	**84%**	**2%**	**84%**	**3%**

58 Relative precision at 90% confidence
59 Relative precision at 90% confidence
60 Relative precision at 90% confidence
61 Relative precision at 90% confidence

5 CONCLUSIONS, FINDINGS, & RECOMMENDATIONS

In this section we provide overall program conclusions followed by each measure's key findings, illustrated with the key symbol, and recommendations, shown by the gear symbol.

Recommendations include supporting context for energy service providers. A list of these recommendations is listed and described in Appendix C per the CPUC ED Impact Evaluation Standard Reporting (IESR) Guidelines.

5.1 Conclusions

The implementation and evaluation of HVAC measures have evolved over the last decade. The changes to programs, measures, and the evaluation of impacts present challenges in assessing and tracking performance. Overall, PY 2019 gross evaluation activities showed savings lower than expectations for nearly all the selected residential HVAC measure groups. The study results showed a high NTGR for the direct install retrofit add on measure groups but very low NTGR for the downstream and upstream replace on burnout furnace measure group. The findings and recommendations include those discovered during the evaluation process such as PA data quality, as well as those targeted for program or savings estimation improvement.

5.2 Overarching findings

Overall, ex post NTGRs are higher than ex ante in all cases except the furnace and RCA measure groups. This is likely a product of the program delivery methods going through contractors and via direct install. Most of these measures are things that few end-users think about on their own, so the proactive program delivery method is a key factor in getting people to install the measures.

With a high rate of net attribution, DNV GL recommends PAs incorporate the direct-install design components of these residential HVAC programs when offering additional energy saving technology that is unfamiliar to most customers, like the coil cleaning, duct sealing, fan controls, and fan motor replacement measure groups in this instance.

5.3 Fan controls

Fan controls evaluated gross savings is very low. Overall, the kWh, peak kW, and therms GRRs for this technology are 19%, 13%, and 0%, respectively. The low electricity savings may result from the competing effects of this technology and smart communicating thermostats, both of which are capable of delaying fan turn-off and were often reportedly installed together. The analysis produced no appreciable gas savings for the heating focused SCG fan motor controller technology.

Investigate whether fan controls and Smart Communicating Thermostats fan delay functionality is redundant. We recommend PAs and the ex Ante review team further study whether the Smart Communicating Thermostat technology provides the same delayed-shutoff function as separate fan controls technology group, and if so, adjust expected savings or eligibility for both technologies.

5.4 Furnaces

Furnaces have low gross savings and net attribution. Both gross and net savings evaluations produced low savings for the furnace measure group. This gross result is driven partly by the outcome of the analysis of high efficiency central furnaces only realizing slightly less than half of their reported savings and partly by the evaluation team's assigning a GRR of 0% for the gravity wall furnace measures due to inadequate program design and lack of documentation that precludes analysis of these furnaces. The net results are driven by a high percentage of survey respondents claiming the program had no influence on the efficiency level of their furnace.

DNV GL recommends the PAs review their furnace technology offerings for viability. The reported gross savings was not considerably realized—even without considering the wholly unrealized savings from the gravity wall furnace technology. The upstream programs' lower NTGR reflects the programs' lack of influence. The preponderance of claims was for gravity wall furnaces; the incentives for gravity wall furnaces went directly to the manufacturer and had no direct effect on the price they charged their distributors. The manufacturer indicated only a 20% increase in sales of high efficiency gravity wall furnaces result from the program.

5.5 RCA

RCA measure shows minimal savings. Overall, the electric consumption (kWh), peak demand (kW), and gas consumption (therms) gross realization rates for this technology are 4%, 2%, and 0%, respectively. The low realization rate is a result of two drivers: the impacts of RCA as modeled are the smallest of any of the technology groups evaluated, and second, total evaluated household savings are smaller than the sum of reported savings. Even though our simulations assumed that the typical system is 12% undercharged (based on studies HVAC 3 and HVAC 5[62,63]) rather than the 8% assumed by PA workpapers, the savings are lower than reported.

Consider discontinuing RCA measure. DNV GL recommends the PAs should investigate the savings for the refrigerant charge adjustment (RCA) technology group and consider discontinuing any HVAC maintenance offering that promotes refrigerant charge adjustments as the evaluation found little impact for this technology group. These results are in line with the 2015 Quality Maintenance (QM) HVAC impact evaluation results where HVAC maintenance programs focusing on RCA provided minimal energy savings with high uncertainty.

[62] Op. cit.
[63] Op. cit.

6 APPENDICES

6.1 Appendix A: Impact Evaluation Standard Reporting (IESR) required reporting−First year and lifecycle savings

Gross Lifecycle Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	1,137	1,777	1.56	0.0%	1.56
PGE	HVAC CONTROLS FAN	16,907	3,857	0.23	0.0%	0.23
PGE	HVAC DUCT SEALING	842	494	0.59	0.0%	0.59
PGE	HVAC MOTOR REPLACEMENT	10,596	3,109	0.29	0.0%	0.29
PGE	HVAC RCA	4,286	234	0.05	0.0%	0.05
PGE	**Total**	**33,768**	**9,471**	**0.28**	**0.0%**	**0.28**
SCE	HVAC CONTROLS FAN	21,544	3,553	0.16	0.0%	0.16
SCE	HVAC DUCT SEALING	2,221	1,620	0.73	0.0%	0.73
SCE	HVAC MOTOR REPLACEMENT	20,964	5,276	0.25	0.0%	0.25
SCE	**Total**	**44,730**	**10,449**	**0.23**	**0.0%**	**0.23**
SCG	HVAC CONTROLS FAN	-25	0	0.00	0.0%	0.00
SCG	HVAC DUCT SEALING	3,474	2,244	0.65	0.0%	0.65
SCG	HVAC FURNACE	0	0			
SCG	**Total**	**3,449**	**2,244**	**0.65**	**0.0%**	**0.65**
SDGE	HVAC COIL CLEANING	380	195	0.51	0.0%	0.51
SDGE	HVAC CONTROLS FAN	3,961	489	0.12	0.0%	0.12
SDGE	HVAC FURNACE	0	0			
SDGE	HVAC MOTOR REPLACEMENT	9	3	0.35	0.0%	0.35
SDGE	HVAC RCA	2,448	49	0.02	0.0%	0.02
SDGE	**Total**	**6,798**	**735**	**0.11**	**0.0%**	**0.11**
	Statewide	***88,745***	***22,900***	***0.26***	***0.0%***	***0.26***

Net Lifecycle Savings (MWh)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	693	1,447	2.09	0.0%	0.61	0.81	0.61	0.81
PGE	HVAC CONTROLS FAN	10,470	3,453	0.33	0.0%	0.62	0.90	0.62	0.90
PGE	HVAC DUCT SEALING	711	518	0.73	0.0%	0.84	1.05	0.84	1.05
PGE	HVAC MOTOR REPLACEMENT	7,000	3,069	0.44	0.0%	0.66	0.99	0.66	0.99
PGE	HVAC RCA	3,598	201	0.06	0.0%	0.84	0.86	0.84	0.86
PGE	**Total**	**22,471**	**8,687**	**0.39**	**0.0%**	**0.67**	**0.92**	**0.67**	**0.92**
SCE	HVAC CONTROLS FAN	14,589	3,352	0.23	0.0%	0.68	0.94	0.68	0.94
SCE	HVAC DUCT SEALING	1,885	1,573	0.83	0.0%	0.85	0.97	0.85	0.97
SCE	HVAC MOTOR REPLACEMENT	14,200	4,839	0.34	0.0%	0.68	0.92	0.68	0.92
SCE	**Total**	**30,674**	**9,763**	**0.32**	**0.0%**	**0.69**	**0.93**	**0.69**	**0.93**
SCG	HVAC CONTROLS FAN	-22	0	0.00	100.0%	0.90			
SCG	HVAC DUCT SEALING	2,937	2,282	0.78	0.0%	0.85	1.02	0.85	1.02
SCG	HVAC FURNACE	0	0						
SCG	**Total**	**2,915**	**2,282**	**0.78**	**-0.8%**	**0.85**	**1.02**	**0.85**	**1.02**
SDGE	HVAC COIL CLEANING	315	204	0.65	0.0%	0.83	1.05	0.83	1.05
SDGE	HVAC CONTROLS FAN	2,389	509	0.21	0.0%	0.60	1.04	0.60	1.04
SDGE	HVAC FURNACE	0	0						
SDGE	HVAC MOTOR REPLACEMENT	5	3	0.62	0.0%	0.60	1.05	0.60	1.05
SDGE	HVAC RCA	2,034	51	0.03	0.0%	0.83	1.05	0.83	1.05
SDGE	**Total**	**4,743**	**768**	**0.16**	**0.0%**	**0.70**	**1.04**	**0.70**	**1.04**
	Statewide	***60,803***	***21,500***	***0.35***	***0.0%***	***0.69***	***0.94***	***0.69***	***0.94***

Gross Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	1.1	1.3	1.18	0.0%	1.18
PGE	HVAC CONTROLS FAN	11.1	1.4	0.13	0.0%	0.13
PGE	HVAC DUCT SEALING	0.9	0.2	0.17	0.0%	0.17
PGE	HVAC MOTOR REPLACEMENT	9.1	2.2	0.24	0.0%	0.24
PGE	HVAC RCA	4.3	0.1	0.03	0.0%	0.03
PGE	**Total**	**26.5**	**5.2**	**0.20**	**0.0%**	**0.20**
SCE	HVAC CONTROLS FAN	7.7	1.0	0.13	0.0%	0.13
SCE	HVAC DUCT SEALING	3.1	0.4	0.15	0.0%	0.15
SCE	HVAC MOTOR REPLACEMENT	15.4	1.6	0.11	0.0%	0.11
SCE	**Total**	**26.2**	**3.1**	**0.12**	**0.0%**	**0.12**
SCG	HVAC CONTROLS FAN	0.0	0.0			
SCG	HVAC DUCT SEALING	4.7	0.6	0.13	0.0%	0.13
SCG	HVAC FURNACE	0.0	0.0			
SCG	**Total**	**4.7**	**0.6**	**0.13**	**0.0%**	**0.13**
SDGE	HVAC COIL CLEANING	0.4	0.2	0.35	0.0%	0.35
SDGE	HVAC CONTROLS FAN	0.9	0.1	0.15	0.0%	0.15
SDGE	HVAC FURNACE	0.0	0.0			
SDGE	HVAC MOTOR REPLACEMENT	0.0	0.0	0.08	0.0%	0.08
SDGE	HVAC RCA	2.8	0.0	0.01	0.0%	0.01
SDGE	**Total**	**4.2**	**0.3**	**0.08**	**0.0%**	**0.08**
	Statewide	***61.6***	***9.2***	***0.15***	***0.0%***	***0.15***

Net Lifecycle Savings (MW)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	0.7	1.1	1.59	0.0%	0.60	0.80	0.60	0.80
PGE	HVAC CONTROLS FAN	6.7	1.3	0.19	0.0%	0.60	0.90	0.60	0.90
PGE	HVAC DUCT SEALING	0.8	0.2	0.22	0.0%	0.83	1.05	0.83	1.05
PGE	HVAC MOTOR REPLACEMENT	5.4	2.1	0.39	0.0%	0.60	0.98	0.60	0.98
PGE	HVAC RCA	3.5	0.1	0.03	0.0%	0.83	0.86	0.83	0.86
PGE	**Total**	**17.1**	**4.8**	**0.28**	**0.0%**	**0.64**	**0.92**	**0.64**	**0.92**
SCE	HVAC CONTROLS FAN	5.3	0.9	0.18	0.0%	0.69	0.94	0.69	0.94
SCE	HVAC DUCT SEALING	2.6	0.4	0.17	0.0%	0.85	0.98	0.85	0.98
SCE	HVAC MOTOR REPLACEMENT	10.6	1.5	0.14	0.0%	0.69	0.92	0.69	0.92
SCE	**Total**	**18.5**	**2.9**	**0.16**	**0.0%**	**0.71**	**0.94**	**0.71**	**0.94**
SCG	HVAC CONTROLS FAN	0.0	0.0						
SCG	HVAC DUCT SEALING	4.0	0.6	0.16	0.0%	0.85	1.02	0.85	1.02
SCG	HVAC FURNACE	0.0	0.0						
SCG	**Total**	**4.0**	**0.6**	**0.16**	**0.0%**	**0.85**	**1.02**	**0.85**	**1.02**
SDGE	HVAC COIL CLEANING	0.4	0.2	0.44	0.0%	0.83	1.05	0.83	1.05
SDGE	HVAC CONTROLS FAN	0.6	0.1	0.26	0.0%	0.60	1.04	0.60	1.04
SDGE	HVAC FURNACE	0.0	0.0						
SDGE	HVAC MOTOR REPLACEMENT	0.0	0.0	0.14	0.0%	0.60	1.05	0.60	1.05
SDGE	HVAC RCA	2.4	0.0	0.01	0.0%	0.83	1.05	0.83	1.05
SDGE	**Total**	**3.3**	**0.3**	**0.10**	**0.0%**	**0.78**	**1.04**	**0.78**	**1.04**
	Statewide	***42.9***	***8.6***	***0.20***	***0.0%***	***0.70***	***0.93***	***0.70***	***0.93***

Gross Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.00
PGE	HVAC CONTROLS FAN	0	0			
PGE	HVAC DUCT SEALING	73	36	0.49	0.0%	0.49
PGE	HVAC MOTOR REPLACEMENT	-110	-32	0.29	0.0%	0.29
PGE	HVAC RCA	0	0	0.00	0.0%	0.00
PGE	**Total**	**-38**	**4**	**-0.10**	**0.0%**	**-0.10**
SCE	HVAC CONTROLS FAN	0	0			
SCE	HVAC DUCT SEALING	134	132	0.98	0.0%	0.98
SCE	HVAC MOTOR REPLACEMENT	0	0			
SCE	**Total**	**134**	**132**	**0.98**	**0.0%**	**0.98**
SCG	HVAC CONTROLS FAN	13	0	0.00	0.0%	0.00
SCG	HVAC DUCT SEALING	245	171	0.70	0.0%	0.70
SCG	HVAC FURNACE	3,914	533	0.14	0.0%	0.14
SCG	**Total**	**4,171**	**704**	**0.17**	**0.0%**	**0.17**
SDGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.00
SDGE	HVAC CONTROLS FAN	0	0			
SDGE	HVAC FURNACE	36	16	0.45	0.0%	0.45
SDGE	HVAC MOTOR REPLACEMENT	0	0			
SDGE	HVAC RCA	0	0	0.00	0.0%	0.00
SDGE	**Total**	**36**	**16**	**0.45**	**0.0%**	**0.45**
	Statewide	***4,304***	***856***	***0.20***	***0.0%***	***0.20***

Net Lifecycle Savings (MTherms)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.60		0.60	
PGE	HVAC CONTROLS FAN	0	0						
PGE	HVAC DUCT SEALING	61	38	0.62	0.0%	0.84	1.05	0.84	1.05
PGE	HVAC MOTOR REPLACEMENT	-70	-31	0.45	0.0%	0.63	0.96	0.63	0.96
PGE	HVAC RCA	0	0	0.00	0.0%	0.83		0.83	
PGE	**Total**	**-9**	**7**	**-0.78**	**0.0%**	**0.23**	**1.78**	**0.23**	**1.78**
SCE	HVAC CONTROLS FAN	0	0						
SCE	HVAC DUCT SEALING	114	125	1.10	0.0%	0.85	0.95	0.85	0.95
SCE	HVAC MOTOR REPLACEMENT	0	0						
SCE	**Total**	**114**	**125**	**1.10**	**0.0%**	**0.85**	**0.95**	**0.85**	**0.95**
SCG	HVAC CONTROLS FAN	11	0	0.00	100.0%	0.90			
SCG	HVAC DUCT SEALING	208	172	0.83	0.0%	0.85	1.01	0.85	1.01
SCG	HVAC FURNACE	2,348	171	0.07	0.0%	0.60	0.32	0.60	0.32
SCG	**Total**	**2,567**	**343**	**0.13**	**0.4%**	**0.62**	**0.49**	**0.61**	**0.49**
SDGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.83		0.83	
SDGE	HVAC CONTROLS FAN	0	0						
SDGE	HVAC FURNACE	22	10	0.45	100.0%	0.60	0.60		
SDGE	HVAC MOTOR REPLACEMENT	0	0						
SDGE	HVAC RCA	0	0	0.00	0.0%	0.83		0.83	
SDGE	**Total**	**22**	**10**	**0.45**	**99.8%**	**0.60**	**0.60**	**0.83**	
	Statewide	***2,694***	***484***	***0.18***	***1.2%***	***0.63***	***0.57***	***0.63***	***0.56***

Gross First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	379	592	1.56	0.0%	1.56
PGE	HVAC CONTROLS FAN	3,381	771	0.23	0.0%	0.23
PGE	HVAC DUCT SEALING	281	165	0.59	0.0%	0.59
PGE	HVAC MOTOR REPLACEMENT	3,532	1,036	0.29	0.0%	0.29
PGE	HVAC RCA	1,429	78	0.05	0.0%	0.05
PGE	**Total**	**9,002**	**2,643**	**0.29**	**0.0%**	**0.29**
SCE	HVAC CONTROLS FAN	4,309	711	0.16	0.0%	0.16
SCE	HVAC DUCT SEALING	740	540	0.73	0.0%	0.73
SCE	HVAC MOTOR REPLACEMENT	4,394	1,106	0.25	0.0%	0.25
SCE	**Total**	**9,443**	**2,357**	**0.25**	**0.0%**	**0.25**
SCG	HVAC CONTROLS FAN	-5	0	0.00	0.0%	0.00
SCG	HVAC DUCT SEALING	1,158	748	0.65	0.0%	0.65
SCG	HVAC FURNACE	0	0			
SCG	**Total**	**1,153**	**748**	**0.65**	**0.0%**	**0.65**
SDGE	HVAC COIL CLEANING	127	65	0.51	0.0%	0.51
SDGE	HVAC CONTROLS FAN	792	98	0.12	0.0%	0.12
SDGE	HVAC FURNACE	0	0			
SDGE	HVAC MOTOR REPLACEMENT	1	0	0.35	0.0%	0.35
SDGE	HVAC RCA	816	16	0.02	0.0%	0.02
SDGE	**Total**	**1,735**	**179**	**0.10**	**0.0%**	**0.10**
	Statewide	***21,333***	***5,926***	***0.28***	***0.0%***	***0.28***

Net First Year Savings (MWh)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	231	482	2.09	0.0%	0.61	0.81	0.61	0.81
PGE	HVAC CONTROLS FAN	2,094	691	0.33	0.0%	0.62	0.90	0.62	0.90
PGE	HVAC DUCT SEALING	237	173	0.73	0.0%	0.84	1.05	0.84	1.05
PGE	HVAC MOTOR REPLACEMENT	2,333	1,023	0.44	0.0%	0.66	0.99	0.66	0.99
PGE	HVAC RCA	1,199	67	0.06	0.0%	0.84	0.86	0.84	0.86
PGE	**Total**	**6,094**	**2,435**	**0.40**	**0.0%**	**0.68**	**0.92**	**0.68**	**0.92**
SCE	HVAC CONTROLS FAN	2,918	670	0.23	0.0%	0.68	0.94	0.68	0.94
SCE	HVAC DUCT SEALING	628	524	0.83	0.0%	0.85	0.97	0.85	0.97
SCE	HVAC MOTOR REPLACEMENT	2,983	1,014	0.34	0.0%	0.68	0.92	0.68	0.92
SCE	**Total**	**6,529**	**2,209**	**0.34**	**0.0%**	**0.69**	**0.94**	**0.69**	**0.94**
SCG	HVAC CONTROLS FAN	-4	0	0.00	100.0%	0.90			
SCG	HVAC DUCT SEALING	979	761	0.78	0.0%	0.85	1.02	0.85	1.02
SCG	HVAC FURNACE	0	0						
SCG	**Total**	**974**	**761**	**0.78**	**-0.5%**	**0.85**	**1.02**	**0.85**	**1.02**
SDGE	HVAC COIL CLEANING	105	68	0.65	0.0%	0.83	1.05	0.83	1.05
SDGE	HVAC CONTROLS FAN	478	102	0.21	0.0%	0.60	1.04	0.60	1.04
SDGE	HVAC FURNACE	0	0						
SDGE	HVAC MOTOR REPLACEMENT	0	0	0.62	0.0%	0.60	1.05	0.60	1.05
SDGE	HVAC RCA	678	17	0.03	0.0%	0.83	1.05	0.83	1.05
SDGE	**Total**	**1,261**	**187**	**0.15**	**0.0%**	**0.73**	**1.04**	**0.73**	**1.04**
	Statewide	***14,859***	***5,592***	***0.38***	***0.0%***	***0.70***	***0.94***	***0.70***	***0.94***

Gross First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	0.4	0.4	1.18	0.0%	1.18
PGE	HVAC CONTROLS FAN	2.2	0.3	0.13	0.0%	0.13
PGE	HVAC DUCT SEALING	0.3	0.1	0.17	0.0%	0.17
PGE	HVAC MOTOR REPLACEMENT	3.0	0.7	0.24	0.0%	0.24
PGE	HVAC RCA	1.4	0.0	0.03	0.0%	0.03
PGE	**Total**	**7.3**	**1.5**	**0.21**	**0.0%**	**0.21**
SCE	HVAC CONTROLS FAN	1.5	0.2	0.13	0.0%	0.13
SCE	HVAC DUCT SEALING	1.0	0.1	0.15	0.0%	0.15
SCE	HVAC MOTOR REPLACEMENT	3.2	0.3	0.11	0.0%	0.11
SCE	**Total**	**5.8**	**0.7**	**0.12**	**0.0%**	**0.12**
SCG	HVAC CONTROLS FAN	0.0	0.0			
SCG	HVAC DUCT SEALING	1.6	0.2	0.13	0.0%	0.13
SCG	HVAC FURNACE	0.0	0.0			
SCG	**Total**	**1.6**	**0.2**	**0.13**	**0.0%**	**0.13**
SDGE	HVAC COIL CLEANING	0.1	0.1	0.35	0.0%	0.35
SDGE	HVAC CONTROLS FAN	0.2	0.0	0.15	0.0%	0.15
SDGE	HVAC FURNACE	0.0	0.0			
SDGE	HVAC MOTOR REPLACEMENT	0.0	0.0	0.08	0.0%	0.08
SDGE	HVAC RCA	0.9	0.0	0.01	0.0%	0.01
SDGE	**Total**	**1.3**	**0.1**	**0.07**	**0.0%**	**0.07**
	Statewide	***16.0***	***2.5***	***0.16***	***0.0%***	***0.16***

Net First Year Savings (MW)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	0.2	0.4	1.59	0.0%	0.60	0.80	0.60	0.80
PGE	HVAC CONTROLS FAN	1.3	0.3	0.19	0.0%	0.60	0.90	0.60	0.90
PGE	HVAC DUCT SEALING	0.3	0.1	0.22	0.0%	0.83	1.05	0.83	1.05
PGE	HVAC MOTOR REPLACEMENT	1.8	0.7	0.39	0.0%	0.60	0.98	0.60	0.98
PGE	HVAC RCA	1.2	0.0	0.03	0.0%	0.83	0.86	0.83	0.86
PGE	**Total**	**4.8**	**1.4**	**0.29**	**0.0%**	**0.65**	**0.92**	**0.65**	**0.92**
SCE	HVAC CONTROLS FAN	1.1	0.2	0.18	0.0%	0.69	0.94	0.69	0.94
SCE	HVAC DUCT SEALING	0.9	0.1	0.17	0.0%	0.85	0.98	0.85	0.98
SCE	HVAC MOTOR REPLACEMENT	2.2	0.3	0.14	0.0%	0.69	0.92	0.69	0.92
SCE	**Total**	**4.2**	**0.7**	**0.16**	**0.0%**	**0.72**	**0.94**	**0.72**	**0.94**
SCG	HVAC CONTROLS FAN	0.0	0.0						
SCG	HVAC DUCT SEALING	1.3	0.2	0.16	0.0%	0.85	1.02	0.85	1.02
SCG	HVAC FURNACE	0.0	0.0						
SCG	**Total**	**1.3**	**0.2**	**0.16**	**0.0%**	**0.85**	**1.02**	**0.85**	**1.02**
SDGE	HVAC COIL CLEANING	0.1	0.1	0.44	0.0%	0.83	1.05	0.83	1.05
SDGE	HVAC CONTROLS FAN	0.1	0.0	0.26	0.0%	0.60	1.04	0.60	1.04
SDGE	HVAC FURNACE	0.0	0.0						
SDGE	HVAC MOTOR REPLACEMENT	0.0	0.0	0.14	0.0%	0.60	1.05	0.60	1.05
SDGE	HVAC RCA	0.8	0.0	0.01	0.0%	0.83	1.05	0.83	1.05
SDGE	**Total**	**1.0**	**0.1**	**0.09**	**0.0%**	**0.80**	**1.04**	**0.80**	**1.04**
	Statewide	***11.3***	***2.4***	***0.21***	***0.0%***	***0.71***	***0.94***	***0.71***	***0.94***

Gross First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Gross	Ex-Post Gross	GRR	% Ex-Ante Gross Pass Through	Eval GRR
PGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.00
PGE	HVAC CONTROLS FAN	0	0			
PGE	HVAC DUCT SEALING	24	12	0.49	0.0%	0.49
PGE	HVAC MOTOR REPLACEMENT	-37	-11	0.29	0.0%	0.29
PGE	HVAC RCA	0	0	0.00	0.0%	0.00
PGE	**Total**	**-13**	**1**	**-0.10**	**0.0%**	**-0.10**
SCE	HVAC CONTROLS FAN	0	0			
SCE	HVAC DUCT SEALING	45	44	0.98	0.0%	0.98
SCE	HVAC MOTOR REPLACEMENT	0	0			
SCE	**Total**	**45**	**44**	**0.98**	**0.0%**	**0.98**
SCG	HVAC CONTROLS FAN	3	0	0.00	0.0%	0.00
SCG	HVAC DUCT SEALING	82	57	0.70	0.0%	0.70
SCG	HVAC FURNACE	196	27	0.14	0.0%	0.14
SCG	**Total**	**280**	**84**	**0.30**	**0.0%**	**0.30**
SDGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.00
SDGE	HVAC CONTROLS FAN	0	0			
SDGE	HVAC FURNACE	2	1	0.45	0.0%	0.45
SDGE	HVAC MOTOR REPLACEMENT	0	0			
SDGE	HVAC RCA	0	0	0.00	0.0%	0.00
SDGE	**Total**	**2**	**1**	**0.44**	**0.0%**	**0.44**
	Statewide	***314***	***130***	***0.41***	***0.0%***	***0.41***

Net First Year Savings (MTherms)

PA	Standard Report Group	Ex-Ante Net	Ex-Post Net	NRR	% Ex-Ante Net Pass Through	Ex-Ante NTG	Ex-Post NTG	Eval Ex-Ante NTG	Eval Ex-Post NTG
PGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.60		0.60	
PGE	HVAC CONTROLS FAN	0	0						
PGE	HVAC DUCT SEALING	20	13	0.62	0.0%	0.84	1.05	0.84	1.05
PGE	HVAC MOTOR REPLACEMENT	-23	-10	0.45	0.0%	0.63	0.96	0.63	0.96
PGE	HVAC RCA	0	0	0.00	0.0%	0.83		0.83	
PGE	**Total**	**-3**	**2**	**-0.78**	**0.0%**	**0.23**	**1.78**	**0.23**	**1.78**
SCE	HVAC CONTROLS FAN	0	0						
SCE	HVAC DUCT SEALING	38	42	1.10	0.0%	0.85	0.95	0.85	0.95
SCE	HVAC MOTOR REPLACEMENT	0	0						
SCE	**Total**	**38**	**42**	**1.10**	**0.0%**	**0.85**	**0.95**	**0.85**	**0.95**
SCG	HVAC CONTROLS FAN	2	0	0.00	100.0%	0.90			
SCG	HVAC DUCT SEALING	69	57	0.83	0.0%	0.85	1.01	0.85	1.01
SCG	HVAC FURNACE	117	9	0.07	0.0%	0.60	0.32	0.60	0.32
SCG	**Total**	**189**	**66**	**0.35**	**1.2%**	**0.68**	**0.79**	**0.67**	**0.79**
SDGE	HVAC COIL CLEANING	0	0	0.00	0.0%	0.83		0.83	
SDGE	HVAC CONTROLS FAN	0	0						
SDGE	HVAC FURNACE	1	0	0.45	100.0%	0.60	0.60		
SDGE	HVAC MOTOR REPLACEMENT	0	0						
SDGE	HVAC RCA	0	0	0.00	0.0%	0.83		0.83	
SDGE	**Total**	**1**	**0**	**0.44**	**98.6%**	**0.60**	**0.60**	**0.83**	
	Statewide	***225***	***110***	***0.49***	***1.5%***	***0.72***	***0.85***	***0.72***	***0.85***

6.2 Appendix B: IESR−Measure groups or passed through measures with early retirement

Per Unit (Quantity) Gross Energy Savings (kWh)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	33.2	11.1	11.1
PGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	109.3	21.9	21.9
PGE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	229.1	76.4	76.4
PGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	3.0	105.6	35.2	35.2
PGE	HVAC RCA	0	0.0%	0.0%	3.0	5.7	1.9	1.9
SCE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	341.8	68.4	68.4
SCE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	80.4	26.8	26.8
SCE	HVAC MOTOR REPLACEMENT	0	32.3%	32.3%	5.0	149.8	31.4	30.0
SCG	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SCG	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	80.1	26.7	26.7
SCG	HVAC FURNACE	0	0.0%	0.0%	20.0	0.0	0.0	0.0
SDGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	13.5	4.5	4.5
SDGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	257.4	51.5	51.5
SDGE	HVAC FURNACE	0	0.0%	0.0%	20.0	0.0	0.0	0.0
SDGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	15.0	393.9	26.3	26.3
SDGE	HVAC RCA	0	0.0%	0.0%	3.0	3.6	1.2	1.2

Per Unit (Quantity) Gross Energy Savings (Therms)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	0.0	0.0	0.0
PGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
PGE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	16.7	5.6	5.6
PGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	3.0	-1.1	-0.4	-0.4
PGE	HVAC RCA	0	0.0%	0.0%	3.0	0.0	0.0	0.0
SCE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SCE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	6.5	2.2	2.2
SCE	HVAC MOTOR REPLACEMENT	0	32.3%	32.3%	5.0	0.0	0.0	0.0
SCG	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SCG	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	6.1	2.0	2.0
SCG	HVAC FURNACE	0	0.0%	0.0%	20.0	29.9	1.5	1.5
SDGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	0.0	0.0	0.0
SDGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SDGE	HVAC FURNACE	0	0.0%	0.0%	20.0	3.3	0.2	0.2
SDGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	15.0	0.0	0.0	0.0
SDGE	HVAC RCA	0	0.0%	0.0%	3.0	0.0	0.0	0.0

Per Unit (Quantity) Net Energy Savings (kWh)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	27.0	9.0	9.0
PGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	97.9	19.6	19.6
PGE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	240.3	80.1	80.1
PGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	3.0	104.3	34.8	34.8
PGE	HVAC RCA	0	0.0%	0.0%	3.0	4.9	1.6	1.6
SCE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	322.5	64.5	64.5
SCE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	78.1	26.0	26.0
SCE	HVAC MOTOR REPLACEMENT	0	32.3%	32.3%	5.0	137.4	28.8	27.5
SCG	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	81.4	27.1	27.1
SCG	HVAC FURNACE	0	0.0%	0.0%	20.0	0.0	0.0	0.0
SCG	HVAC CONTROLS FAN	1	0.0%		5.0	0.0	0.0	0.0
SDGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	14.1	4.7	4.7
SDGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	268.3	53.7	53.7
SDGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	15.0	413.6	27.6	27.6
SDGE	HVAC RCA	0	0.0%	0.0%	3.0	3.8	1.3	1.3
SDGE	HVAC FURNACE	1	0.0%		20.0	0.0	0.0	0.0

Per Unit (Quantity) Net Energy Savings (Therms)

PA	Standard Report Group	Pass Through	% ER Ex-Ante	% ER Ex-Post	Average EUL (yr)	Ex-Post Lifecycle	Ex-Post First Year	Ex-Post Annualized
PGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	0.0	0.0	0.0
PGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
PGE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	17.5	5.8	5.8
PGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	3.0	-1.1	-0.4	-0.4
PGE	HVAC RCA	0	0.0%	0.0%	3.0	0.0	0.0	0.0
SCE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SCE	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	6.2	2.1	2.1
SCE	HVAC MOTOR REPLACEMENT	0	32.3%	32.3%	5.0	0.0	0.0	0.0
SCG	HVAC DUCT SEALING	0	0.0%	0.0%	3.0	6.1	2.0	2.0
SCG	HVAC FURNACE	0	0.0%	0.0%	20.0	9.6	0.5	0.5
SCG	HVAC CONTROLS FAN	1	0.0%		5.0	0.0	0.0	0.0
SDGE	HVAC COIL CLEANING	0	0.0%	0.0%	3.0	0.0	0.0	0.0
SDGE	HVAC CONTROLS FAN	0	0.0%	0.0%	5.0	0.0	0.0	0.0
SDGE	HVAC MOTOR REPLACEMENT	0	0.0%	0.0%	15.0	0.0	0.0	0.0
SDGE	HVAC RCA	0	0.0%	0.0%	3.0	0.0	0.0	0.0
SDGE	HVAC FURNACE	1	0.0%		20.0	2.0	0.1	0.1

6.3 Appendix C: IESR−Recommendations resulting from the evaluation research

Study ID	Study Type	Study Title	CPUC Study Manager
Group A HVAC Sector	Impact Evaluation	Impact Evaluation Report - Residential HVAC Sector – Program Year 2019	Peng Gong

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
1	All programs	NTGRs are higher than claimed.	Ex post NTGRs are higher than ex ante in all cases except the furnace and RCA measure groups. This is likely a product of the program delivery methods going through contractors and via direct install. Most of these measures are things that few end-users think about on their own, so the proactive program delivery method is a key factor in getting people to install the measures.	DNV GL recommends PAs incorporate the direct-install design components of these residential HVAC programs when offering additional energy saving technology that is unfamiliar to most customers, such as the coil cleaning, duct sealing, fan controls, and fan motor replacement measure groups in this evaluation.	All PAs	

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
2	SDGE3279, 3P-Res-Comprehensive Manufactured-Mobile Home; SCE-13-TP-001, Comprehensive Manufactured Homes; PGE21009, Direct Install for Manufactured and Mobile Homes; PGE21008, Enhance Time Delay Relay; SDGE3211, Local-CALS-Middle Income Direct Install (MIDI); SCE-13-SW-001G, Residential Direct Install Program; PGE210011, Residential Energy Fitness program; PGE21006, Residential HVAC; SCG3702, RES-Residential Energy Efficiency Program; SDGE3212, SW-CALS-Residential HVAC-QI/QM	Evaluated gross savings of fan controls are very low.	Overall, the kWh, peak kW, and therms GRRs for this measure group are 19%, 13%, and 0%, respectively. The low electricity savings may result from the competing effects of this technology and smart communicating thermostats, both of which are capable of delaying fan turn-off and were often reportedly installed together. The analysis produced no appreciable gas savings for the heating focused SCG fan motor controller technology.	Investigate whether fan controls and Smart Communicating Thermostats fan delay functionality is redundant. We recommend PAs and the ex Ante review team further study whether the Smart Communicating Thermostat technology provides the same delayed-shutoff function as the separate fan controls technology group, and if so, adjust expected savings or eligibility for both technologies.	All PAs	SCE17HC052, rev0; WPSCGREHC161128A, Rev1; PGECOHVC150, Rev4; WPSDGEREHC0024, Rev3

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
3	SCG3702, RES-Residential Energy Efficiency Program; SCG3706, RES-Residential HVAC Upstream; SDGE3302, SW-CALS - Residential HVAC Upstream	Furnaces have low gross savings and net attribution.	Both gross and net savings evaluations produced low savings for the furnace measure group. This gross result is driven partly by the outcome of the analysis of high efficiency central furnaces only realizing slightly less than half of their reported savings and partly by the evaluation team's assigning a GRR of 0% for the gravity wall furnace measures due to inadequate program design and lack of documentation that precludes analysis of these furnaces. The net results are driven by a high percentage of survey respondents claiming the program had no influence on the efficiency level of their furnace.	DNV GL recommends the PAs review their furnace technology offerings for viability. Reported gross savings were not considerably realized—even without considering the wholly unrealized savings from the gravity wall furnace technology. The upstream programs' lower NTGR reflects the programs' lack of influence. The preponderance of claims was for gravity wall furnaces; the incentives for gravity wall furnaces went directly to the manufacturer and had no direct effect on the price they charged their distributors. The manufacturer indicated only a 20% increase in sales of high efficiency gravity wall furnaces result from the program.	SCG, SDG&E	WPSCGREHC130115A, Rev4; WPSDGEREHC1063, Rev0

Rec #	Program or Database	Summary of Findings	Additional Supporting Information	Best Practice/Recommendations	Recipient	Affected Workpaper or DEER
4	SDGE3279, 3P-Res-Comprehensive Manufactured-Mobile Home; PGE21009, Direct Install for Manufactured and Mobile Homes; PGE21008, Enhance Time Delay Relay; SDGE3211, Local-CALS-Middle Income Direct Install (MIDI); PGE210011, Residential Energy Fitness program; PGE21006, Residential HVAC; SDGE3207, SW-CALS-MFEER	RCA measure shows minimal savings.	Overall, the electric consumption (kWh), peak demand (kW), and gas consumption (therms) gross realization rates for this technology are 4%, 2%, and 0%, respectively. The low realization rate is a result of two drivers: the impacts of RCA as modeled are the smallest of any of the technology groups evaluated, and second, total evaluated household savings are smaller than the sum of reported savings. Even though our simulations assumed that the typical system is 12% undercharged (based on studies HVAC 3 and HVAC 5) rather than the 8% assumed by PA workpapers, the savings are lower than reported.	DNV GL recommends the PAs should investigate the savings for the refrigerant charge adjustment (RCA) technology group and consider discontinuing any HVAC maintenance offering that promotes refrigerant charge adjustments, as the evaluation found little impact for this technology group. These results are in line with the 2015 Quality Maintenance (QM) HVAC impact evaluation results where HVAC maintenance programs focusing on RCA provided minimal energy savings with high uncertainty.	SDG&E, PG&E	PGECOHVC139, Rev6; WPSDGEREHC0032, Rev2

6.4 Appendix D: Two-stage billing analysis methodology

DNV GL estimated energy savings from residential HVAC measures using the two-stage approach detailed below. This approach is from the UMP which served as the primary basis for the CalTRACK methodology. DNV GL used daily data for the analysis, which is also consistent with the CalTRACK consumption data analysis approach. Detailed step-by-step methods to perform the two-stage approach are described below:

Stage 1. Individual premise analysis

For each premise in the analysis, whether in the participant or comparison group,

- Fit a premise-specific degree-day regression model (as described in Step 1, below) separately for the pre- and post- periods.
- For each period, pre and post, use the coefficients of the fitted model with CZ2018 degree-days to calculate normalized annual consumption (NAC) for that period (as described in Step 2, below).
- Calculate the difference between the premise's pre- and post-period NAC (as described in Step 3, below).

The site-level modeling approach was originally developed for the Princeton Scorekeeping Method (PRISM™) software.[64] The theory regarding the underlying structure is discussed at length in materials for and articles about the software.[65]

Step 1. Fit the basic stage 1 model

The degree-day regression for each premise and year (pre or post) is modeled as:

$$E_m = \mu + \beta_H H_m + \beta_C C_m + \varepsilon_m$$

where:

E_m	=	Daily consumption per day *m* or average consumption per day during interval *m*;
H_m	=	Specifically, $H_m(\tau_H)$, average daily heating degree-days at the base temperature (τ_H) during meter read interval m, based on daily or daily average temperatures over those dates;
C_m	=	Specifically, $C_m(\tau_C)$, average daily cooling degree-days at the base temperature (τ_C) during meter read interval m, based on daily or daily average temperatures over those dates;
μ	=	Average daily baseload consumption estimated by the regression;
β_H, β_C	=	Heating and cooling coefficients estimated by the regression;
ε_m	=	Regression residual.

64 PRISM (Advance Version 1.0) Users' Guide. Fels, M.F., and k Kissock, M.A. Marean and C. Reynolds. Center for Energy and Environment Studies, Princeton New Jersey. January 1995.

65 Energy and Buildings: Special Issue devoted to Measuring Energy Savings: The Scorekeeping Approach. Margaret F. Fels, ed. Volume 9 Numbers 1&2, February/May 1986.

Step 2. Select individual models ***fixed versus variable degree-day base***

In the simplest form of this model, the degree-day base temperatures (τ_H) and (τ_C) are each pre-specified for the regression. For each site and time period, only one model is estimated, using these fixed, pre-specified degree-day bases.

The fixed base approach can provide reliable results if the savings estimation uses NAC only, and the decomposition of usage into heating, cooling, and base components is not of interest. When data used in the Stage 1 model span all seasons NAC is relatively stable across a range of degree-day bases. However, the decomposition of consumption into heating, cooling, or base load coefficients is highly sensitive to the degree-day base.

The alternative is a variable degree-day approach. The variable degree-day approach entails the following: (1) estimating each site-level regression and time period for a range of heating and cooling degree-day base combinations, including dropping heating and/or cooling components; and (2) choosing an optimal model (with the best fit, as measured by the coefficient of determination R^2) from among all of these models.

The variable degree-day approach fits a model that reflects the specific energy consumption dynamics of each site. In the variable degree-day approach, for each site and time, the degree-day regression model is estimated separately for all unique combinations of heating and cooling degree-day bases, β_H and β_C, across an appropriate range. This approach includes a specification in which one or both weather parameters are removed.

Degree-days and fuels

For the modeling of natural gas consumption, it is unnecessary to include a cooling degree-day term. For the modeling of electricity, a model with heating and cooling terms should be tested, even if the premise is believed not to have electric heat or air conditioning. Thus, the range of degree-day bases must be estimated for each of these options:

- Electricity Consumption Model
  - Heating-Cooling model (HC)
  - Cooling Only (CO)
  - Heating Only (HO)
  - No degree-day terms (mean value)
- Gas Consumption Models
  - Heating Only (HO)
  - No degree-day terms (mean value)

Degree-days and set-points

If degree-days can vary, the estimated heating degree-day base τ_H will approximate the highest average daily outdoor temperature at which the heating system is needed for the day. The estimated cooling degree-day base τ_C will approximate the lowest average daily outdoor temperature at which the house cooling system is needed for the day. These base temperatures reflect both average thermostat set-points and building dynamics such as insulation, internal and solar heat gains, etc. The average thermostat set-points may include variable behavior related to turning on the air conditioning or secondary heat sources. If heating or cooling are not present or are of a magnitude that is indistinguishable amidst the natural variation, then the model without a heating or cooling component may be the most appropriate model, using the R^2 model selection rule.

For each premise, time, and model specification (HC, HO or CO), the final degree-day bases (values of τ_H and τ_C) that give the highest R^2, along with the coefficients μ, β_H, β_C estimated at those bases will be selected. Models with negative parameter estimates should be removed from consideration, although they rarely survive the optimal model selection process.

Step 3. Calculate NAC using stage 1 models

To calculate NAC for the pre- and post-installation periods for each premise and timeframe, combine the estimated coefficients $\mu, \beta_H,$ and β_C with the annual normal-year or typical meteorological year (TMY) degree-days H_0 and C_0 that have been calculated at the site-specific degree-day base(s), τ_H and τ_C. Thus, for each pre and post period at each individual site, use the coefficients for that site and period to calculate NAC.

$$NAC = \mu * 365 + \beta_H * H_0 + \beta_C * C_0$$

This example puts all premises and periods on an annual and normalized basis. The same approach can be used to put all premises on a monthly basis and/or on an actual weather basis. Using this approach to produce consumption on a monthly and actual weather basis is an alternative approach to calendarization that may be preferable to the simple pro-ration of billing intervals under some circumstances.

Step 4. Calculate the change in NAC

For each site, the difference between pre- and post-program NAC values (ΔNAC) represents the change in consumption under normal weather conditions.

Stage 2. Cross-sectional analysis

Difference-in-difference whole house savings model

The first-stage analysis estimates the weather-normalized change in usage for each premise. The second stage combines these to estimate the aggregate program effect by using a cross-sectional analysis of the change in consumption relative to premise characteristics based on a difference-in-difference model.

The difference-in-difference model is given by:

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

In this model, i subscripts a household and T is a treatment indicator that is 1 for residential HVAC measure households and 0 for comparison homes. The effect of the program is captured by the coefficient estimate of the term associated with the treatment indicator, β.

Decomposition of whole-home savings

Engineering models that simulate savings for measures and measure bundles offered by the direct install programs will form the basis of the decomposition of whole home savings. The engineering models will be based on DEER residential prototypes adjusted as appropriate from recent evaluation results. These models will provide estimates of the percent reduction in cooling and heating load from their respective baselines, for individual measures and for measure bundles offered by direct install programs. Separate percent savings will be produced by climate zone and housing type.

The estimated reductions will be for measures offered both on a first in (standalone) basis and as part of a bundle on a last in (incremental/marginal) basis. The following lists the types of relative measure savings (in percent terms) the engineering simulation models provide that will be used to disaggregate whole-home estimated savings:

- First in (standalone) measure savings.
- Bundle savings for the bundles claimed in the PY2019 DI programs, accounting for the majority of savings (about 80%) across the included programs.
- Marginal savings for each measure in a bundle re-scaling the last-in marginal savings so the total matches the bundle savings.
- Marginal savings for each measure in a bundle re-scaling the first-in marginal savings so the total matches the bundle savings.

Results from engineering simulations are used as inputs in statistically adjusted engineering (SAE) models to decompose whole-home savings (obtained customer-level DID regression model) to measure-level savings. Engineering simulation results provide more realistic inputs to SAE models, which enables these models to separate the effects of different measures more accurately. The common SAE model is specified as:

$$\Delta NAC_i = \alpha + \sum_m \rho_{Hm} SH_{mi} + \sum_m \rho_{Cm} SC_{mi} + \varepsilon_i$$

where SH_{mi} and SC_{mi} are engineering or ex ante estimates of annual heating and cooling savings for measure m and customer i, and ρ_{Hm} and ρ_{Cm} are coefficients of the model that measure heating and cooling saving realization rates.

In this study, the engineering-based savings estimates are developed as fractions of pre-program annual cooling and heating load, because it is not practical to develop simulation models for every customer individually. To produce the energy savings quantities, SH_m and SC_m, for each customer, it is necessary to multiply the simulation-based savings fractions of each measure and load type by the pre-installation heating and cooling usage estimated from the customer-level DID regression model.

However, if we make that basic substitution in the common SAE model, we would have pre-program normalized annual heating and cooling included on both sides of the equation—on the left as part of $preNAC$ and on the right as scalars factors in SH_m and SC_m. This relationship creates an endogeneity problem, that is, a built-in correlation between the regressors and predictors.[66] Endogeneity leads to biased estimates of the coefficients. We estimate a log SAE model, described below, to circumvent this endogeneity.

[66] To see the endogeneity more clearly, we expand the basic SAE model as:

$$postNAC_i - preNAC_i = postNAC_i - (preNACBase_i + preNACH_i + preNACC_i) = \lambda + \sum_m \rho_{Hm} f_{Hm} preNACH_i + \sum_m \rho_{Cm} f_{Cm} preNACC_i + \varepsilon_i$$

Here $NACBASE$ is normalized annual baseload; $NACH$ is normalized annual heating load; $NACC$ is normalized annual cooling load; and f_{Hm} and f_{Cm} are simulation-based savings fractions for heating and cooling for measure m. Here we see the components $NACH$ and $NACC$ on both sides of the equation.

The log SAE model DNV GL intends to use is based on the savings percentages from the simulation models described above to decompose whole-home, heating and cooling savings into measure savings. This model differs fro00m common SAE models in two ways:

6. Because the engineering estimates are on a percentage basis, rather than having customer-specific estimates in energy units, the regression is of the change in log NAC against the engineering estimates of percent savings.
7. Because the percent savings from the engineering models are most meaningful as percentages of heating and cooling rather than whole-home load, the dependent variable uses heating or cooling load with separate log regression models estimated for each. The model for each is given by:

$$\log(PostNAC_{li}) - \log(PreNAC_{li}) = l_l - \sum_m \rho_{ml} f_{mli} + \varepsilon_i$$

where:

$\log(\text{Post}NAC_{li})$	=	Log of post period NAC for customer i and load type l (l = heating or cooling load)
$\log(\text{Pre}NAC_{li})$	=	Log of pre period NAC for customer i and load type l (l = heating or cooling load)
l_l	=	Non-program related change
f_{mli}	=	The simulation-based savings fractions or percentages for load type l (heating and cooling) of measure m, for the climate zone and building type and measure bundle type of customer i ; not this term is 0 for non-participant households used as matches
ρ_{ml}	=	the heating or cooling realization rate for measure
ε_i	=	Regression residual

Total savings for measure m and load type l is given by:

$$S_{ml} = exp(\widehat{\rho_{ml}} \sum_i f_{mli} + se^2/2) * PreNAC_{li}$$

where the summation is over all customers with the measure.[67] Unit savings per measure then is this estimated total saving divided by the number of customers with the measure. This approach will be applied to direct install programs offering smart thermostats as well as other measures.

Some of the details remaining to be resolved include:

- If we have engineering estimates of fractional savings f_{ml} based both on a first-in assumption and on a last-in assumption, we will review how different these are after re-scaling. We may use only one, only the other, or a blend.
- It's difficult to estimate separate realization rates for different measures or measure groups, particularly if some of the estimated savings are small. We may group some measures together in the SAE model to produce a common realization rate that will be applied to the engineering estimates from each.

[67] Since the model used to estimate load savings is in log terms, it requires exponentiation to go from log scale back to the original (energy) units. This back transformation requires the use of a bias correction factor $se^2/2$, where se is the standard error of the regression.

6.5 Appendix E: Net-to-gross methods: Identifying causal pathways of influence

DNV GL has utilized the causal pathway approach to assessing attribution and free-ridership for upstream and midstream programs in California. The basic approach is to assess the program's influence on midstream market actor (e.g.: distributors) behaviors, then assess how those midstream actor behaviors affect the decision-making of the end-user purchasers. For PY2019 upstream furnaces, DNV GL only assessed the program's effects on the midstream market actors and assumed those behavior changes would fully affect end-user decision-making.

Our methodology assumed that there were three main causal pathways of influence which impacted the HVAC equipment distributor, installation contractors, and end-users. We derived these assumptions from the program logic model provided from the IOUs and conversations with program implementers. Distributors and buyers are both important when evaluating program attribution of this nature, and both were taken into consideration to formulate an overarching attribution score.

The three main causal pathways of program influence included:

1. The program influenced distributors to **stock** high efficiency units, and what was in stock influenced what buyers purchased when their unit failed. This causal pathway was driven by the assumption that when buyers replace existing equipment in an urgent situation (replace on failure in five days or less), the stocking habits of distributors would be most influential.
2. The program encouraged distributors to **upsell or promote** high efficiency units, and buyers were influenced by the upselling and promotional efforts to purchase high efficiency units rather than standard efficiency models. Note, there is a circular relationship between upselling and stocking. Based on our conversations with program staff, distributors stock what sells and sell what is in stock. Therefore, program effects on stocking can have an indirect effect on upselling. We attempt to address this indirect effect through framing questions, but ultimately only capture a singular program influence on upselling that includes indirect effects through stocking, coaching, the rebates, and other program activities.
3. The program offers distributors a rebate on high efficiency units but does not encourage nor require distributors to reduce the **price** of high efficiency units or pass along the rebate to buyers. The rebate is intended to compensate the distributors for indirect costs to maintaining high efficiency stock and upselling high efficiency units. Some distributors might pass rebates through to buyers, and in those cases, buyers might be influenced by the lower prices of these high efficiency units.

Thus, the primary attribution pathway for the program is through increasing upselling and promotion of high efficiency units. The program's intended effects on stock and price are captured within the upselling and promotion pathway. Table 6-1 shows the researchable questions themes that represent the three causal pathways across distributors and buyers.

Table 6-1. Question themes across causal pathways for distributors and buyers

Causal Pathways	Distributor Question Theme
Stock	1. Did the program influence distributor to carry more high efficiency (HE) stock?
Promotion/Upsell	2. What was the program influence on encouraging the distributor to promote or upsell the units?
Price of Units	3. Did the distributor pass on some or all of the incentive to buyers?

To calculate the total program attribution score, we multiplied these three free-ridership scores together. We explore this calculation further below, but the overall approach captures multiple paths of attribution, as well as partial attribution when it exists.

Distributor attribution calculation

We began by asking distributors an open-ended question about how they think the program has impacted their business, and then asked questions related to the three causal pathways. Last, we asked distributors questions about how the program influenced their sales of high efficiency units. We used screening questions at the beginning of the survey to ensure that the respondent was the best person to speak to about program influence across all of these areas. For all these questions, we asked follow-up questions clarifying why the respondent gave certain answers. This allowed us to make sure that the respondent understood the question, and to collect additional information on how the program might have influenced their business practices. Updates from the interview guide used for PY2017 included adding some questions about specific program activities we learned of during the interview with program managers (e.g. regular meetings between program managers and distributors to coach on upselling). We also used a more specific matrix of technologies and sizes for the key attribution questions.

The following flowcharts diagram how the Stocking Attribution, Upselling Attribution, Price Attribution, and Sales Attribution scores were calculated for the distributors.

Figure 6-1. Detailed distributor causal pathway scoring: stocking

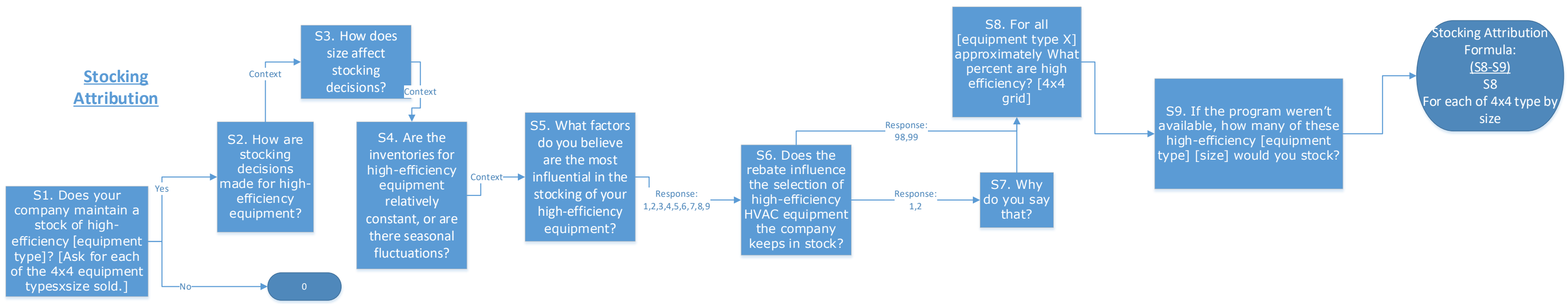


Figure 6-2. Detailed distributor causal pathway scoring: upselling

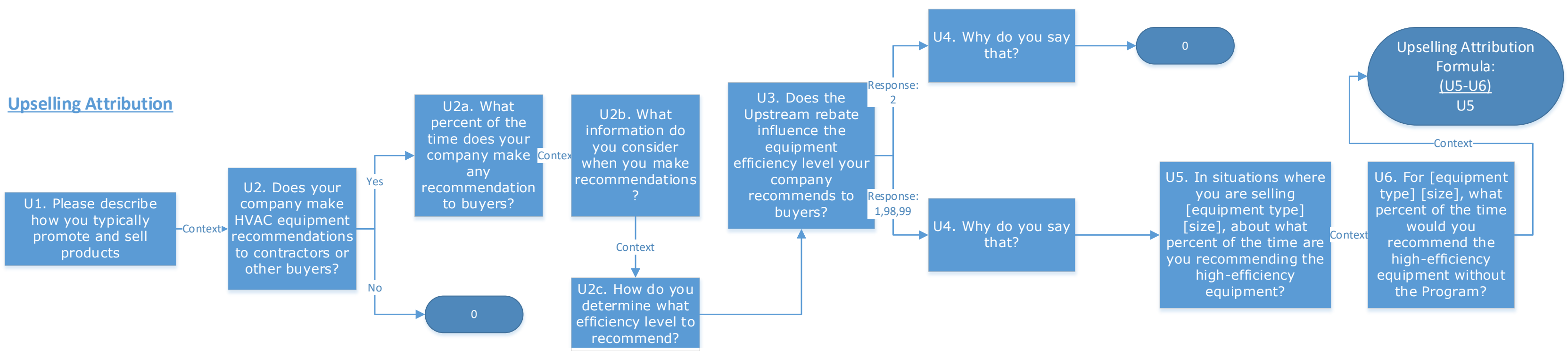


Figure 6-3. Detailed distributor causal pathway scoring: price

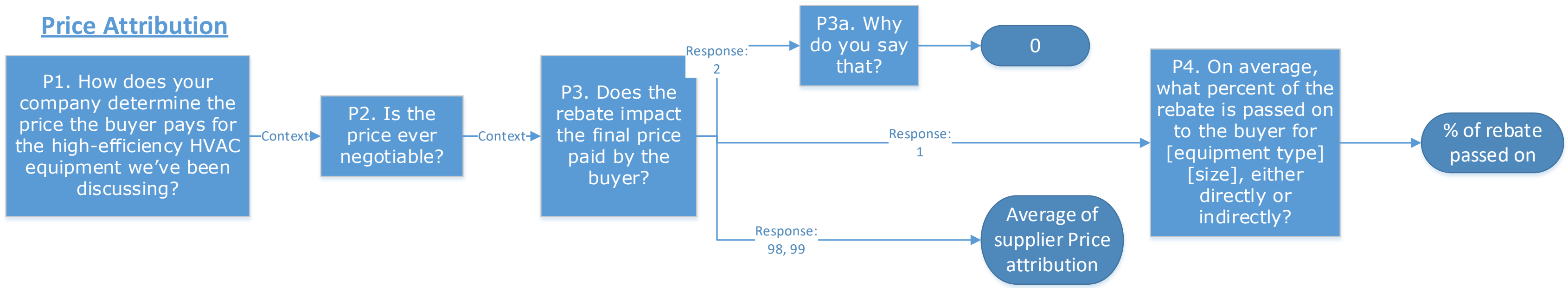
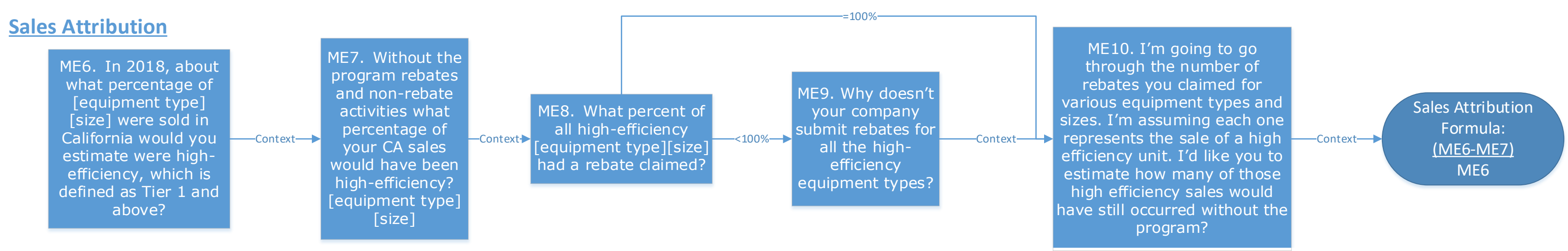


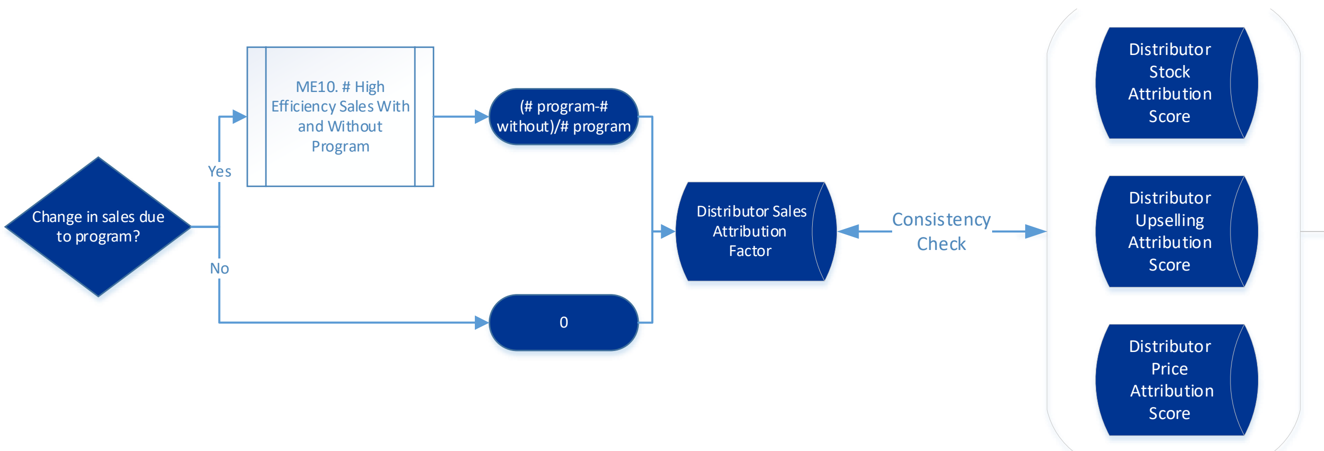
Figure 6-4. Detailed distributor causal pathway scoring: sales



Consistency Check

To check if sales were influenced by the program, we asked the distributors to describe the current percent of their sales for baseline units, and percent of their sales that are for high efficiency units, across different unit types and sizes. We then asked the distributors to estimate what baseline and high efficiency sales would have been without the upstream program. We used the change in these numbers to calculate a measurable impact the program had on distributors' sales. Figure 6-5. shows how we calculated sales attribution and used the result to check consistency across the other attribution scores.

Figure 6-5. Distributor attribution consistency check



6.6 Appendix F: Net-to-gross methods: Downstream programs

For the residential HVAC impact evaluation, DNV GL used NTG scoring methods similar to those used for other residential measures such as smart thermostats. DNV GL'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 (kWh, kW, therms) 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 HVAC measure program participants. The applicability of the quantity dimension varied by the type of survey respondent. The various PA-delivered programs that provided HVAC measures to residential customers gave rebates for one-unit HVAC installations per household. For example, a single-family participant could only receive a single HVAC coil cleaning and the quantity dimension is not applicable. However, survey respondents who are multifamily property managers[29] could be responsible for multiple homes and could have decided to install multiple measures across units. Thus, the quantity dimension is applicable to multifamily survey respondents.

Table 6-2. Free-ridership elements

Survey Respondents	Free-ridership Dimension	Question Wording	Answer	Free-ridership Score
Participants (occupants)	Timing – (FRt)	If the program didn't offer an [HVAC measure] on {installed date}, when would you have purchased and installed it/them…?	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 responses
Property managers	Timing – (FRt)	If the program didn't offer an [hvac measure] on {installed date}, when would you have purchased and installed it/them…?	At the same time or sooner	1
			(1 to 48 months later property managers only)	(48 - # of months)/48
			(More than 48 months property managers only)	0
			Never	0
			Don't know	Average of non-Don't know responses
Participants (occupants) Property managers	Efficiency (FRe)	(Furnaces) Without the program(s), I would have installed a furnace at a level of efficiency that was…?	Same or higher than program requirements (95% or higher AFUE)	1

Survey Respondents	Free-ridership Dimension	Question Wording	Answer	Free-ridership Score
			Lower than required by the program (86 to 90% AFUE)	0.75 [0]
			Slightly lower than required by program (91 to 94% AFUE)	0.5 [0]
			Significantly lower than required by program (81 to 85% AFUE)	0.25
			Minimum efficiency allowed per building code (80% AFUE)	0
			Would not have installed a furnace]	0
			Don't know	Average of non-Don't know responses
Participants (occupants) Property managers	Efficiency (FRe)	(Fan Motor Controls) We would also like to know what influence the {Q3} program had (if any) on the decision to have a technician install a new FAN MOTOR on the furnace. Without the program, which of the following would you have done?	Replace with a high efficiency motor (i.e. brushless) similar to the one I received from the program	1
			Replace with a standard motor	0
			Repair the existing equipment	0
			Nothing, no replacement or repair	0
			Don't know	Average of non-Don't know responses
Property managers	FRq	Without {Q3}'s program how many of the following upgrades would you have completed at your own expense?	0%, 100%, 1% to 100% in 10% increments	0%, 100%, or mid-point of increment

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

Equation 1: Free-ridership Scoring Algorithm for single-family participants

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

Equation 2: Free-ridership Scoring Algorithm for multifamily participants

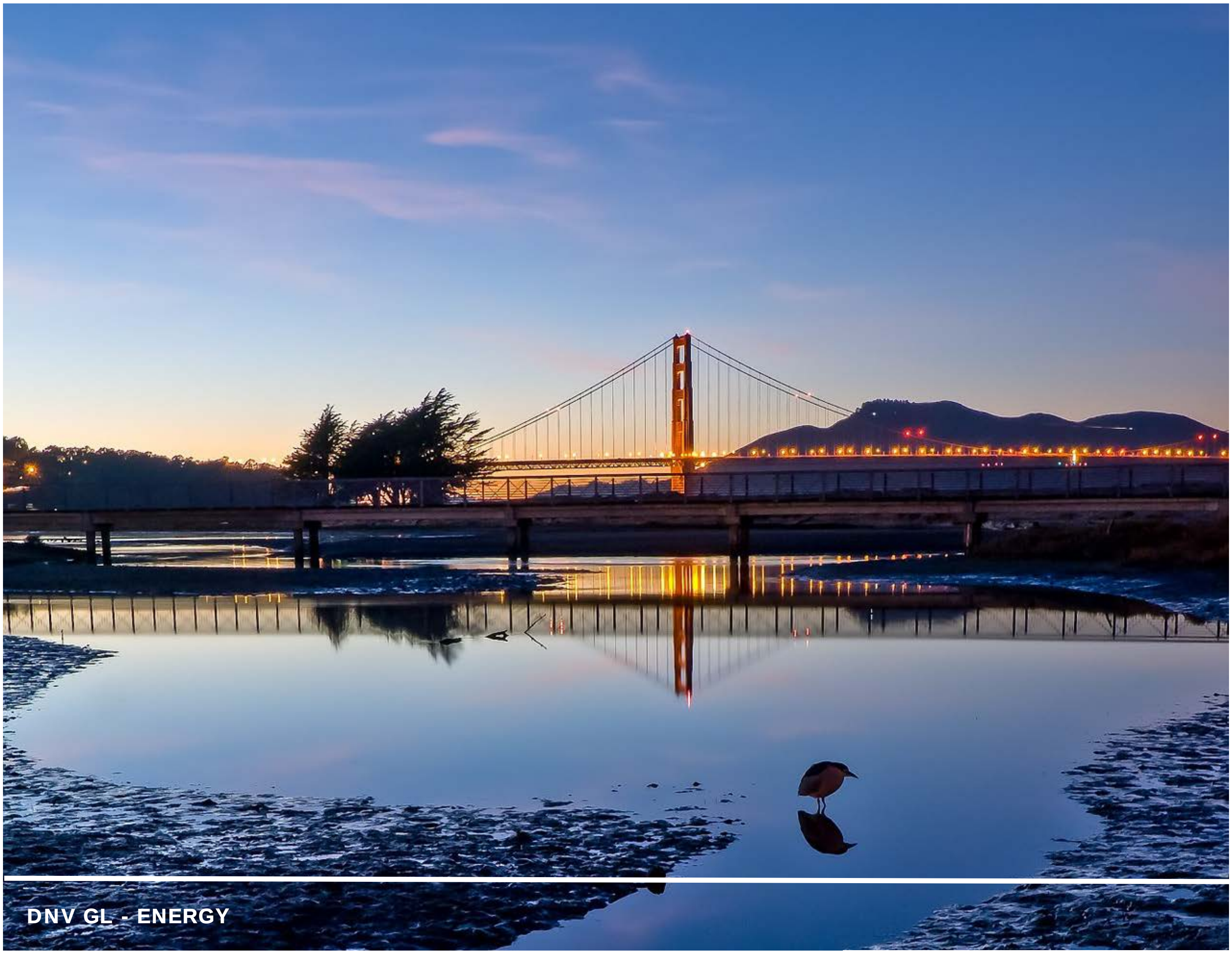
$$\text{Free-ridership} = FR_t * FR_e * FR_q$$

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

Results from the free-ridership analysis based on the participant (occupants) or property manager surveys are summarized in Section. 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.

6.7 Appendix G: Data collection and sampling memo

DNV·GL



SAFER, SMARTER, GREENER

Sampling and Data Collection Memo

HVAC Sector – Program Year 2019

CALIFORNIA PUBLIC UTILITIES COMMISSION
EM&V Group A

August 27, 2020

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1 OVERVIEW

This document outlines the sampling and data collection plan for the Heating, Ventilating, and Air Conditioning (HVAC) sector for the Program Year (PY 2019) impact evaluation of deemed savings under the Group A contract with the California Public Utilities Commission (CPUC).

Our sampling and data collection efforts under Deliverable 7 (Data Collection and Sampling Approach) are designed to meet the needs of Deliverable 1 (Research and Evaluation Workplans), Deliverable 8 (Program Analysis and Recommendations), Deliverable 9 (Gross Savings Estimates) and Deliverable 10 (Net Savings Estimates). As part of Deliverable 7, we have developed a sampling and data collection strategy to serve the needs of these deliverables at the required rigor levels.

Our approach to measure group selection is described in Section 2, while Section 3 contains the sampling approach and sample summary. Section 4 covers data collection for both gross and net savings estimates. Finally, the Appendices include the data collection instruments we will use to gather data for quantifying our gross and net savings.

2 MEASURE GROUP SELECTION

Working with Commission staff, the evaluation team determined which measure groups to evaluate for PY 2019 based on the following selection process. First, the deemed HVAC annual savings claims[1] were grouped by PY 2019 ESPI (Efficiency Savings and Performance Incentive) and Non-ESPI measure groups. Next, each measure group's contribution to savings (kWh, kW, therms) was ranked and these individual rankings were combined to create an overall HVAC sector savings contribution ranking. The selection process then took into consideration whether a measure group had been evaluated recently and looked at year-over-year trends in the savings claims for that measure group. The Commission staff and the evaluation team sought Stakeholder engagement on both the process and the proposed measure groups selection through the HVAC Project Coordination Group meetings and the HVAC Workplan engagement process with the Program Administrators (PAs).

2.1 Measure groups selected for evaluation

The measure groups selected for this evaluation are primarily from the statewide list of HVAC ESPI uncertain measures. For the PY 2019 evaluation, we have selected nine measure groups across the HVAC sector—five are ESPI measure groups and four are non-ESPI. The four ESPI measure groups, and their market sectors, are:

- HVAC PTAC[2] Controls (Commercial)
- HVAC Motor Replacement (Residential)
- HVAC Duct Sealing (Residential)
- HVAC Maintenance (Residential)
- HVAC Refrigerant Charge Adjustment, or RCA (Residential)

The non-ESPI measure groups selected for evaluation are:

- HVAC Rooftop/Split Systems (Commercial)
- HVAC Controls Fan (Residential)
- HVAC Coil Cleaning (Residential)
- HVAC Furnace (Residential)

Our evaluation team will perform both gross savings and net attribution assessments on eight of the nine measure groups; one measure group (the Rooftop/Split System, a non-ESPI measure group) will receive gross-only assessment.

Table 1 shows a complete list of the selected measure groups for 2019 and specifies the measure groups that are selected for evaluation of gross savings estimates and/or net program attribution for PY 2019 along with their ESPI status.

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[1] The evaluation team ranked measure groups by first-year gross savings and lifetime net savings and found the rankings had no substantial differences.

[2] PTAC and PTHP are acronyms for the packaged terminal air conditioning/heat pump systems frequently found serving lodging guest rooms.

Table 1. PY 2019 HVAC sector measure groups for evaluation

Measure Group	Sector	2019 ESPI	Gross Savings Evaluation	Net Savings Evaluation
HVAC PTAC Controls	Commercial	Yes	Yes	Yes
HVAC Rooftop/Split System	Commercial	No	Yes	No
HVAC Motor Replacement	Residential	Yes	Yes	Yes
HVAC Duct Sealing	Residential	Yes	Yes	Yes
HVAC Refrigerant Charge Adjustment (RCA)	Residential	Yes	Yes	Yes
HVAC Maintenance	Residential	Yes	Yes	Yes
HVAC Controls Fan	Residential	No	Yes	Yes
HVAC Coil Cleaning	Residential	No	Yes	Yes
HVAC Furnace	Residential	No	Yes	Yes

Table 2 shows the savings claims for the PY 2019 HVAC Sector ESPI and non-ESPI measure groups selected for evaluation, as well as a line item grouping all other deemed HVAC measure group claims that are not under evaluation.

Table 2. PY 2019 first year gross savings tracking data claims for deemed HVAC ESPI and Non-ESPI evaluation measure groups

ESPI Uncertain Measure List	Measure Groups	kW	% kW	kWh	% kWh	Therms	% Therms
ESPI	HVAC Controls PTAC	6,280	20%	17,831,593	27%	0	0%
	HVAC Duct Sealing	2,898	9%	2,180,142	3%	150,712	15%
	HVAC Maintenance	0	0%	0	0%	0	0%
	HVAC Motor Replacement	6,331	20%	7,985,195	12%	-37,043	-4%
	HVAC RCA	2,756	9%	2,657,242	4%	-126	0%
Non-ESPI	HVAC Coil Cleaning	651	2%	662,781	1%	-59	0%
	HVAC Controls Fan	3,997	13%	14,428,949	22%	285,954	28%
	HVAC Furnace	0	0%	0	0%	316,441	31%
	HVAC Rooftop/Split Systems	5,305	17%	10,285,837	16%	-57,133	-6%
	HVAC measure groups not evaluated	3,035	10%	9,870,631	15%	349,873	35%
Total Deemed HVAC		**31,253**	**100%**	**65,902,370**	**100%**	**1,008,619**	**100%**

3 SAMPLING

Section 3 describes the applied sampling approach and sample summary.

3.1 Sampling approach

Depending on the measure group being evaluated, the sampling methodology employs either a census approach or a stratified ratio estimation model. A census approach will study every unit in a population whereas a stratified ratio estimation approach will study a subset of units in a population. The stratified ratio approach first places participants into segments of interest (in this case, by evaluated measure group) and then into strata by size, measured in kWh and therm savings. The methodology then estimates appropriate sample sizes based on an assumed error ratio.

The error ratio is the ratio-based equivalent of a coefficient of variation (CV). The CV measures the variability (standard deviation or root-mean-square difference) of individual evaluated values around their mean value, as a fraction of that mean value. Similarly, the error ratio measures the variability (root-mean-square difference) of individual evaluated values from the ratio: Evaluated = Ratio* Reported, as a fraction of the mean evaluated value. Thus, to estimate the precision that can be achieved by the planned sample sizes, or conversely the sample sizes necessary to achieve a given precision level, it is necessary to develop a preliminary estimate of the error ratio for the sample components.

In practice, error ratios cannot be determined until after the data are collected and savings are evaluated, and therefore need to be estimated. The sample design and projected precision are therefore based on assumed error ratios from experience with similar work. A simple verification study may use an error ratio of 0.50. A study looking to measure annual or peak consumption would have a higher estimated error ratio based on past metering studies, somewhere between 0.7 and 1.0 depending on buildings and climates covered.[3] For the PTAC measure group, the only group receiving a stratified ratio sampling approach, we assume an overall error ratio of 0.8 for each Program Administrator (PA) based on previous experience with similar studies. This evaluation will measure a set of conditions and compare them to current simulation model assumptions. Analysis will be possible across PAs but Climate Zones (CZs) with small population savings will have small or no samples.

For the stratified ratio estimation sample design, first we defined sampling frames for each of the sampled measure groups being evaluated. The sampling frame for each measure group is the list of savings claims records under that measure group from which the sampling units are selected. Once sampling frames are defined, we stratified the population on the claimed savings (kWh or therms). Then we determined the target precisions and designed the sample to achieve ±10% relative precision for each measure group at the 90% confidence level assuming an error ratio of 0.8. Once sample size was calculated, we randomly chose primary sample points from the population in each stratum. We have selected a sample large enough to achieve the targeted number of completed cases, after the response rates are considered. We have also selected a backup sample in case we need to replace any sample points. This most often happens with sites that can't be visited or evaluated for some reason.

3.2 Measure group sampling overview

From the nine selected PY 2019 measure groups, only the commercial HVAC PTAC Controls measure group gross impact effort will use a stratified ratio estimation approach for sample design. As described just above, the sampling methodology for HVAC PTAC Controls measure group will employ a stratified ratio estimation model that places participants into strata by kWh savings. The methodology then estimates appropriate sample sizes based on an assumed error ratio.

The determination of the net program attribution for the commercial HVAC PTAC Controls measure group will use a census approach targeting the utility customers who are the decision makers being influenced by the programs.

The commercial HVAC Rooftop/Split Systems measure group will not involve primary data collection from PY 2019 participants and is not subject to a sampling treatment. For the Rooftop/Split System measure group, the evaluation team will perform a discrepancy analysis between PY 2018 ex-post results and claimed PY 2018 ex-ante savings and true-up the unit energy savings (UES) values as appropriate for measures within this group.

The gross and net impacts of all the residentially-focused HVAC measure groups (Duct Sealing, Maintenance, Motor Replacement, RCA, Coil Cleaning, Controls Fan, and Furnace) will use the census approach where the entire program population will be evaluated via the AMI data analysis/simulation modeling and remote data collection methods described in detail in the PY 2019 workplan and

[3] *California Commercial End-Use Survey,* Itron, Inc.; JJ Hirsh and Associates; KEMA Inc.; *ADM* 2006, CALMAC ID CEC 0023.01

summarized here. The gross AMI meter data analysis approach will use 12 months of pre- and post-retrofit kW and therms to estimate the household level savings. This analysis will also be supported by bottom-up International Performance Measurement and Verification Protocol (IPMVP) Option-D simulation approach; our team will use eQUEST simulation modeling of the DEER residential prototypes to generate measure savings estimates that will inform the disaggregation of meter-level savings to measure-group-level savings. To determine net program attribution of programs offering the HVAC residential measure groups, we will take a census approach to conduct either market actor (i.e. equipment distributors) or end-user surveys, depending on the programs' intervention point in the market.

3.3 PTAC Controls measure groups sample design

The PTAC controls measure group contains 192 sites that claimed savings during PY 2019. About 84% of the sites (162 sites) participated in Pacific Gas and Electric (PG&E) programs and 16% (30 sites) took part in the program from San Diego Gas and Electric (SDG&E). Southern California Edison (SCE) and Southern California Gas (SCG) had no PTAC Controls measures in the 2019 program year.

For gross savings of the PTAC controls measure group, DNV GL's team will design the sample to achieve +/-10% relative precision at the 90% confidence level. In order to achieve this relative precision at the 90% confidence level with an assumed error ratio of 0.80, a total of 85 sample sites are required. Table 3 shows the PY 2019 PTAC controls measure group populations and the sample sizes for each program by PA.

Table 3. PTAC Controls gross sample by PA and program

PA	Program	Sample Size	Population Size	Relative Precision[4]	Program Savings (kWh)	Error Ratio
PG&E	Hospitality Program	53	126	12.7%	14,473,895	0.80
	Local Government Energy Action Resources (LGEAR)	3	5	44.7%	217,216	0.80
	Association of Monterey Bay Area Governments (AMBAG)	3	8	74.2%	293,185	0.80
	Silicon Valley	3	4	26.5%	212,107	0.80
	San Francisco	8	19	21.7%	1,484,175	0.80
	PG&E Total	**70**	**162**	**11.3%**	**16,680,578**	**0.80**
SDG&E	SW-COM-Deemed Incentives-HVAC Commercial	15	30	19.0%	1,151,015	0.80
	SDG&E Total	**15**	**30**	**19.0%**	**1,151,015**	**0.80**
Statewide Total		**85**	**192**	**10.6%**	**17,831,593**	**0.80**

In order to be able to produce meaningful results for each program a minimum sample size was established. Due to the small population sizes of some of the PGE programs (N<10) a minimum

[4] Anticipated relative precision at 90% confidence

sample size of 3 was selected. For all programs with larger populations and savings of at least 10% of the PA program, the sample was allocated to maximize the overall relative precision of the sample design.

Table 4 shows the stratification and inclusion probability for the PTAC controls sample design.

Table 4. PTAC Controls measure group stratification

PA	Program	Stratum	Maximum	Population Size	Program Savings (kWh)	Sample Size	Inclusion Probability[5]
PG&E	Hospitality Program	1	88,605	49	2,119,164	10	0.204
		2	114,475	25	2,498,762	10	0.400
		3	152,150	20	2,661,129	10	0.500
		4	192,425	16	2,792,092	10	0.625
		5	311,017	12	2,992,619	9	0.750
		6	371,425	4	1,410,129	4	1.000
	LGEAR	1	65,025	4	118,406	2	0.500
		2	98,810	1	98,810	1	1.000
	AMBAG	1	99,345	8	293,185	3	0.375
	Silicon Valley	1	51,653	3	72,534	2	0.667
		2	139,573	1	139,573	1	1.000
	San Francisco	1	20,625	7	98,125	2	0.286
		2	30,000	5	123,125	1	0.200
		3	80,000	3	153,125	1	0.333
		4	354,420	4	1,109,800	4	1.000
SDG&E	SW-COM-Deemed Incentives-HVAC Commercial	1	18,496	9	101,444	3	0.333
		2	23,291	6	125,117	2	0.333
		3	32,196	5	141,308	2	0.400
		4	46,581	3	126,729	2	0.667
		5	4,392	3	180,327	2	0.667
		6	38,374	4	476,090	4	1.000

[5] Inclusion probability is the chance that the population element becomes part of a sample.

4 DATA COLLECTION

As part of this task the evaluation team is developing a data collection framework to improve consistency, facilitate comparison of results across data collection efforts, reduce the time for survey development, minimize review time, and facilitate quality assurance and quality control. The framework includes:

- Guidance and templates for instrument development
- Standard question modules for common survey batteries
- Recommendations on QA/QC procedures
- Guidance on data collection management
- Guidance on sample management

The details of developing this data collection framework are described in Appendix B of the Workplan document.

4.1 Data collection instruments

Where appropriate, we will base data collection on our existing Commission-approved data collection instruments. We have worked with Commission staff and other stakeholders to assess, revise, and approve these data collection instruments prior to collecting any data.

4.1.1 Commercial measure groups

4.1.1.1 HVAC PTAC Controls

For the PY 2019 evaluation of PTAC Controls measures, we will conduct interviews with end users at participating facilities (primarily over the phone, supplemented with web-based interviews if required) using utility-provided contact and equipment information. The phone interview will include questions to verify measure installation and persistence and to establish the equipment's baseline control scheme. The information collected will be used to update installation rates and refine gross savings estimates for PTAC Controls measures.

At the time of this writing, the evaluators assume that on-site visits will not be feasible for PY 2019 data collection, due to the ongoing COVID-19 pandemic. As a result, the phone interview with contacts at participating end user facilities will be the primary data collection mechanism. The data collection plan for PTAC control measures will include:

- **Installation Characteristics**: The most critical characteristics evaluators will inquire about include the facility type, building vintage, and installed unit quantity per site. A list of additional items to be recorded are included in the appendices.
- **Equipment Nameplate**: Evaluators will confirm the characteristics of the installed PTAC controllers as well as the PTAC units being controlled. Evaluators will request the contact to provide photographs of the equipment and nameplates and/or submit documentation to objectively verify installation and characteristics.
- **Operating Characteristics**: Evaluators will ask the facility contact about typical room operation and set-point schedules. Trended operating data will be requested to be shared directly from the site or through the installation vendor. The evaluator will obtain the heating and cooling

temperature set-point schedules for weekdays, weekends and holidays as well as temperature set-points for occupied and non-occupied periods. The evaluator will ask for a list of holidays observed at the facility (if applicable) as well as typical occupancy patterns and any notable changes in operation from before and after the project took place (for instance, changes due to the COVID-19 pandemic.)

- **Additional data:** These include any documentation confirming measure installation or providing additional insight into how the units are controlled before and after the project took place.

  The gross data collection instruments are in Appendix D (PG&E) and Appendix E (SDG&E.) The net data collection instrument for end users is in Appendix C**.**

4.1.1.2 Rooftop/Split Systems

No onsite data collection is proposed for Rooftop/Split System measure group. The evaluation team will address the discrepancy between the ex-ante and ex-post savings estimate via simulation and eventually propose to true up the UES of this measure group based on the simulation results. The evaluation team will use the best available models including DEER resources, the California electronic Technical Reference Manual (eTRM) [6], and other data sources (including existing EM&V data) to develop robust independent savings impact estimates.

4.1.2 Residential HVAC measure groups

4.1.2.1 Coil Cleaning, Controls Fan, Furnaces, Maintenance, Fan Motor Replacement, RCA, & Duct Sealing

For PY 2019 we will use energy consumption analysis for estimating gross energy savings for these measure groups. Gross savings estimates will be based on metered consumption data and will not require data collection instruments. See Section 3.2 for a discussion of our methodology for producing gross savings estimates.

We will complete the gross savings estimates deliverable by January 2021 and incorporate the results into the evaluation report. We will submit the draft gross savings deliverable to Commission staff prior to finalization.

4.1.2.2 Net attribution data collection

We will perform net evaluations for all residential HVAC measure groups under evaluation for PY 2019.

To support our net savings estimates we plan to interview end-user utility customers or property managers for direct install programs and HVAC equipment distributors for upstream programs. Some of the specific efforts under this plan are:

- Reviewing the program PIP and conduct interviews with program managers to discuss program theory on influencing alternate equipment types where applicable
- Conducting end-user interviews to assess free ridership for the downstream programs
- Conducting market actor interviews with participating distributors to assess program influence

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[6] https://www.caetrm.com/

DNV GL's team has demonstrated effective stakeholder management in previous evaluation cycles by including a review process for all data collection instruments—not only with the Energy Division Program Manager, but also with PA program evaluation staff and other stakeholders. This process is particularly beneficial for evaluations of newer programs or programs where there have been significant changes that necessitate input from PA staff to refine and improve instruments. We have posted data collection instruments to Basecamp or other CPUC collaboration site.

The net data collection instruments are in Appendix A (furnace distributors for upstream programs) and Appendix B (residential customers for Direct Install and downstream programs.)

4.1.2.3 Data sources

Data sources and applicable measure groups are summarized in Table 5 below. This table shows some of the data sources and data collection activities across the measure groups for this sector. Data will be used to provide a robust, accurate, and defensible ex-post estimate of measure impacts. Remote data collection efforts will focus on verifying the simulation model inputs. We provide additional details in Table 5.

Table 5. Summary of data sources and applicable measure groups

Data Sources	Description	Applicable Measure Group(s)
Program Tracking Data	PA program data includes number of records, savings per record, program type, name, measure groups, measure description, incentives etc.	• PTAC Controls • Rooftop/Split System • Fan Motor Replacement • Duct Sealing • RCA • Maintenance • Controls Fan • Coil Cleaning • Furnace
Program Monthly Billing Data	PA billing data including kWh and therms	• PTAC Controls • Fan Motor Replacement • Duct Sealing • RCA • Maintenance • Controls Fan • Coil Cleaning • Furnace
Program Advanced Metering Infrastructure (AMI) Data	Detailed, time-based energy consumption information	• PTAC Controls • Fan Motor Replacement • Duct Sealing • RCA • Maintenance • Controls Fan • Coil Cleaning • Furnace
Project-Specific Information	Project folders include scope of work, energy audit reports, equipment model and serial numbers, nominal efficiency, test results, project costs, etc.	• PTAC Controls • Rooftop/Split System
Manufacturer Data Sheet	Data sheets Include equipment specifications such as horsepower (HP), efficiency, capacity, etc.	• PTAC Controls • Rooftop/Split System

Data Sources	Description	Applicable Measure Group(s)
Telephone/Web Surveys	Includes surveys of customers, distributors, other market actors, and PA program staff.	• PTAC Controls • Fan Motor Replacement • Duct Sealing • RCA • Maintenance • Controls Fan • Coil Cleaning • Furnace
On-site Surveys	Includes verifying measure installation, gathering measure performance parameters such as efficiency, schedules, setpoints, building characteristics etc.	• N/A
End-use metering	Includes performing spot measurements, short-term metering with data loggers, performance measurements	• N/A

The following list defines the data sources identified above in **Table 5**:

- **Program tracking data.** Each of the Program Administrators (PAs) will provide and upload program tracking data onto a centralized server. We will then analyze, clean, re-categorize, and reformat these datasets, if necessary. For programs and measures, the impact evaluation team will review PA monthly reports and actual program tracking data to reconcile actual versus reported claims, thereby validating PA tracking data uploads.
- **Project-specific information.** The PAs maintain paper and/or electronic files for each application or project in their energy efficiency programs. These can contain various pieces of information such as email correspondence written by the utility's customer representatives documenting various aspects of a given project such as the measure effective useful life (EUL), incremental cost, measure payback with and without the rebate. As part of the file review process, we will thoroughly review these documents to assess their reasonableness.
- **Data sheets from equipment manufacturers.** As part of the gross data collection, we will request technical specifications of the evaluated equipment from manufacturers and equipment vendors. These data sheets typically include performance parameters of the equipment such as horsepower, efficiency, capacity, energy efficiency ratio (EER).
- **Telephone / web surveys of participating customers and distributors.** Both gross and net deliverables will require telephone/web surveys. We will perform surveys with customers, distributors, other market actors, and PAs.
- **On-site surveys.** Because of the COVID-19 pandemic, DNV GL is not planning any on-site visits during this evaluation period.
- **End-use metering.** Because of the COVID-19 pandemic, DNV GL is not planning end-use metering during this evaluation period.

Appendix A HVAC RESIDENTIAL FURNACE DISTRIBUTOR NET DATA COLLECTION FORM

CPUC HVAC 2019
NTG Res Furnace Di:

Appendix B HVAC RESIDENTIAL MEASURE GROUP DATA COLLECTION FORM

CPUC PY2019
RES_HVAC NTG Surv

Appendix C HVAC COMMERCIAL PTAC CONTROLS NET DATA COLLECTION FORM

CPUC GROUP A
PTAC Net Data Colle

Appendix D HVAC COMMERCIAL PTAC CONTROLS GROSS DATA COLLECTION FORM PG&E

CPUC A PTAC
Controls_Data Colle

Appendix E HVAC COMMERCIAL PTAC CONTROLS GROSS DATA COLLECTION FORM SDG&E

CPUC A PTAC Controls_Data Colle

About DNV GL

6.8 Appendix H: Residential end-user web survey

CPUC PY2019 Residential Combined (HVAC/RES)

Participant Online Survey

The combined HVAC and Res RoadMap Measure Groups captured in this survey are as follows:

IMPORT DATA FIELDS

- [SITE ID]
- [PA]
- [PROGRAM NAME]
- [INSTALL DATE]
- [CONTRACTOR NAME FOR DI MEASURES]
- [STREET ADDRESS, CITY]
- [YEAR INSTALLED] > EXCLUDE IF ALL = 2019
- TOTAL MEASURE COUNT
- MEASURE NAMES a-h (As shown in table, in individual columns)

Measure Group & Counts
(Section 1.4) SMART THERMOSTAT TYPE
(Section 1.5) HVAC MAINTENANCE ASSESSMENT (DESCRIBE)
(Section 1.5) HVAC COIL CLEANING
(Section 1.5) HVAC REFRIGERANT CHARGE ADJUSTMENT
(Section 1.6) HVAC DUCT TEST & SEAL
(Section 1.7) HVAC INDOOR FAN CONTROLER
(Section 1.8) HVAC INDOOR FAN MOTOR REPLACEMENT
(Section 1.9) HVAC FURNACE (DESCRIBE)

- Measure count (individual)
- Summary level (if >1) [Low end package cost] to [High end package cost]
- COMBINED MEASURE LIST WITH COMMA SEPERATOR (see Q22)
- SAMPLE WAVE COUNT

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

From: [PAs]

"SCE Energy Efficiency Evaluation"<donotreply_survey@sce.com>

"PG&E Energy Efficiency Evaluation"<feedback@survey.pge.com>

"SoCalGas Energy Efficiency Evaluation"<donotreply@survey.socalgas.com>

"SDG&E Energy Efficiency Evaluation"<donotreply@survey.sdge.com>

Subject line: Tell us about your experience with your [PA] sponsored HVAC energy efficient progam

Dear [PA] Customer,

Would you be one of the respondents who will help us meet our survey completion goals today? We need customers like you to provide us with feedback regarding your experience with your [PA] sponsored Smart Thermostat and/or HVAC equipment and services program. As a participant in [PA]'s program, your opinions are important. [PA] and the California Public Utilities Commission (CPUC) would like your input and perspectives to understand how to best structure future energy efficiency programs.

We're requesting your participation today in a 15-minute survey. To thank you for your participation your household will be entered in a drawing for a $100 incentive. The information gathered will be used solely for research purposes and your individual responses will be kept confidential.

To get started click on this link: [ST]:

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

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

Peng Gong/Peter Franzese
California Public Utilities Commission
505 Van Ness Ave.
San Francisco, CA 94102

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

1.1 Online Survey – Introduction Page

Smart Thermostat / HVAC Survey

Survey Instructions

Hello,

This 15-minute survey is being conducted by an independent research organization with households that participated in the [PA] sponsored [PROGRAM_NAME] program to install energy efficiency equipment and services.

While completing the survey, please provide responses that reflect not just yourself but rather all household members that share the same electric bill. Do your best to answer all questions.

This study is sponsored by the California Public Utilities Commission (CPUC) and will be used to help plan programs to benefit homeowners and save energy. Responses to this survey will be kept strictly confidential and reported only in the aggregate.

Need Help? DNV GL has been hired to manage this study supported by [PA] and the California Public Utilities Commission. DNV GL support representatives can be reached by emailing us at: support@impact.dnvgl.com

1.2 INTRODUCTION

Screener: Do you currently have an active account with [PA] at this address: [Q1]?
  Yes (Continue)
  No (Thank and terminate)

1. Do you have more than one central heating/cooling (HVAC) system in your home?
    Yes
    No
    Don't know

2. According to [PA]'s records, in 2019 one or more of the following heating/cooling (HVAC) related improvements were made to the home. Are you aware of these equipment/service(s) upgrades? Select all that apply: [TABLE ONLY POPULATED WITH MEASURES THAT HAVE UNIT COUNT >0; 'Number of units' POPULATED FROM TRACKING DATA IF RESPONDENT RESPONDS 'Yes' TO AWARNESS QUESTION; FOR HVAC MAINTENANCE MEASURES, 'Number of units' = 'Number of systems' REPORTED IN Q1 DUE TO ORIGINAL UNITS BEING REPORTED IN CAP/TON]

Equipment and Services	Aware of installation? (Yes/No/Don't know)	Number of units installed/ serviced	Are the number of units correct? (Yes/No/Don't know)	[IF NO] Please record correct quantity (record '0' if no measures installed)
1a. SMART THERMOSTAT				
1b. HVAC MAINTENANCE ASSESSMENT				

1c. HVAC COIL CLEANING				
1d. HVAC REFRIGERANT CHARGE ADJUSTMENT				
1e. HVAC DUCT SEALING				
1f. HVAC INDOOR FAN MOTOR CONTROLLER				
1g. HVAC INDOOR MOTOR REPLACEMENT				
1h. FURNACE				

[IF ALL Q1 Awareness = Don't Know]

3. Is there someone else living in the home who may be familiar with this/these equipment/service(s) upgrades?
   - [RECORD] First and last name:
   - [RECORD] Phone number:
   - [RECORD] Email address:

   [THANK AND TERMINATE]

4. Which of the following factors influenced your decision to make these upgrades to your heating/cooling system? Please select all that apply.
   - Utility rebate / discount
   - Utility offering was either low or no cost to me
   - HVAC contractor recommendation
   - Reduced my energy bills
   - Non-energy impacts (e.g. improve comfort)
   - Reduced carbon emissions / climate change
   - Family/friend/neighbor recommendation
   - Property manager requested
   - Equipment failure or end of useful life
   - Equipment needed maintenance
   - Ease of use (e.g., smart thermostat)
   - Good for the environment
   - Other (please specify)
   - Don't know (exclusive)

5. [SKIP IF ONLY 1 MEASURE INSTALLED IN Q2] [PA]'s records show your household had the following HVAC upgrades made to your home [REPEAT LIST FROM TABLE ABOVE HERE]. When thinking about the decision to have these upgrades performed how did you approach the project?
   - I thought of all the equipment and services installed as a PACKAGE > *GoTo Q6*
   - I thought of each piece of equipment and service individually > *GoTo Q15*
   - Don't know > *GoTo Q3*

1.3 OVERALL FREE RIDER MODULE

In this survey, we would like to learn about the role of [PA]'s program in your decision-making process to go ahead with this/these HVAC upgrades. [PA]'s program offering may have included a free or lower-cost thermostat, HVAC service(s) such as a tune-up for a heater or air conditioner, and/or upgrades like a new motor or a rebate for a high efficiency furnace. The offering may have been discounted through a rebate or provided at no cost if your income qualified.

6. Without [PA]'s program offering (rebate/service), how likely would you have been to initiate and complete the entire project at an approximate full price of [Low end package cost] to [High end package cost]? Would you say…
   Very likely
   Somewhat likely
   A 50/50 chance
   Somewhat unlikely
   Very unlikely
   Don't know

7. [SKIP IF ONLY FURNACE MEASURE INSTALLED] Without [PA]'s program offering in 2019, when would you have completed this project?
   At the same time or sooner
   1 to 24 months later
   More than 24 months later
   Never
   Don't know

8. [IF Q7 = Q7.A2] Please specify the number of months:
   [RECORD #]:

9. Without [PA]'s program offering, which of the following equipment and/or services **would you have completed at your own expense**? Please select all that apply. ['Number of units' UPDATED BASED ON RESPONSE TO Q1; HIDE ROWS THAT ARE NOT APPLICABLE]

Equipment and Services	Number of units
1a. SMART THERMOSTAT	
1b. HVAC MAINTENANCE ASSESSMENT	
1c. HVAC COIL CLEANING	
1d. HVAC REFRIGERANT CHARGE ADJUSTMENT	
1e. HVAC DUCT SEALING	
1f. HVAC INDOOR FAN MOTOR CONTROLLER	
1g. HVAC INDOOR FAN MOTOR REPLACEMENT	
1h. FURNACE	
NONE OF THESE (exclusive)	
ALL OF THESE (exclusive)	

10. [SKIP IF Q9 ≠ "NONE OF THESE"] Why wouldn't you have completed any part of this project? Please select all that apply.
    Unaware it needed to be done
    Not a priority
    Cost to upgrade/too expensive
    Not responsible to maintain equipment
    Difficult to find a qualified contractor
    Unsure that energy savings are worth the cost
    Don't know (exclusive)
    Other

11. [SKIP IF Q9 = "NONE OF THESE"] Why would you have completed some or all of the project without [PA]'s program offering (incentives/services)? Please select all that apply.
    Save money/energy
    Equipment failure or end of useful life
    Health and safety

Improve comfort
Remodel or renovation
Recommendation from a contractor
Good for the environment
Appeal to prospective or current renters
Ease of use
Don't know (exclusive)
Other

12. [SKIP IF NO SMART THERMOSTAT MEASURES INSTALLED] Smart thermostats come in a variety of models. There are BASIC models that cost about $150-$200 (e.g., Nest E and Ecobee 3 lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest Learning 3rd Gen and Ecobee 4).

    If the program didn't offer a smart thermostat rebate in 2019, which model would you have likely purchased?
    Would have purchased the BASIC model smart thermostat
    Would have purchased the UPGRADED model smart thermostat
    Would have purchased a standard programmable thermostat (e.g., without smart capabilities)
    Would NOT have purchased a thermostat at all

13. [SKIP IF NO FURNACE MEASURES INSTALLED] Without the program(s), would you have installed a furnace at a level of efficiency that was…?
    Same or higher than program requirements (95% or higher AFUE)
    Slightly lower than required by program (91 to 94% AFUE)
    Higher than allowable minimum (86 to 90% AFUE)
    Slightly higher than allowable minimum (81 to 85% AFUE)
    Minimum allowable efficiency (80% AFUE)
    Would not have installed a furnace
    Don't know

14. [SKIP IF NO MOTOR REPLACEMENT MEASURES INSTALLED] We would also like to know what influence the program had (if any) on the decision to have an HVAC technician install a new Fan Motor on the air conditioning unit. Without the program, which of the following would you have done?
    Nothing, no replacement or repair
    Repair the existing equipment
    Replace with a standard motor
    Replace with a high efficiency motor (i.e. brushless)
    Other (specify)
    Don't know

[SKIP TO Q39, SECTION 1.10]

1.4 SMART THERMOSTAT FREE RIDER MODULE

[SKIP IF NO SMART THERMOSTAT MEASURES INSTALLED]

First, we would like to know about the smart thermostat provided or rebated by the program.

15. Is the smart thermostat still in place and operational in your home?
    Yes [GOTO Q17]
    No > *[Goto Q16]*

16. Why was the thermostat removed/non-operational? [GOTO Q22]

17. Which brand and model did you purchase or receive?
    - Nest E (basic model)
    - Nest Learning 3rd Generation (upgrade model)
    - EcoBee 4 (upgrade model)
    - EcoBee 3 Lite model (basic model)
    - Other, e.g., Eco Factor, Emerson, Honeywell, Lux, Radio Thermostat, etc., specify:
    - Don’t know (exclusive)

For this next set of questions, we would like to know about your decision to install the smart thermostat and the role the [PA]’s rebate program had (if any).

18. What is the likelihood you would have purchased the same smart thermostat, if the rebate was not available?
    - Very likely
    - Somewhat likely
    - A 50/50 chance
    - Somewhat unlikely
    - Very unlikely

19. If the program didn’t offer a rebate for this smart thermostat in 2019, when would you have purchased it…?
    - At the same time or sooner
    - 1 to 24 months later
    - More than 24 months later
    - Never
    - Don't know

20. [IF Q19 = Q19.A2] Please specify the number of months:
    - [RECORD #]:

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

    If the program didn’t offer a smart thermostat rebate in 2019, which model would you have likely purchased?

    - Would have purchased the BASIC model smart thermostat
    - Would have purchased the UPGRADED model smart thermostat
    - Would have purchased a standard programmable thermostat (e.g., without smart capabilities)
    - Would NOT have purchased a thermostat at all

1.5 HVAC ASSESSMENT, MAINTENANCE, AND REPAIR FREE RIDER MODULE

[SKIP IF NO COIL CLEANING, RCA, MAINTENANCE MEASURES INSTALLED]

For these next set of questions, we would like to know how your decision to have <u>HVAC assessment, maintenance, and repairs</u> performed may have changed in the absence of the program incentive or no cost service.

Coil cleaning: A maintenance process performed by a HVAC service technician, whereby the outdoor air conditioning unit’s condenser coils are cleaned of debris. This process can help improve the efficiency of your air conditioning unit.

Refrigerant charge adjustment: A maintenance process performed by a HVAC service technician, whereby the refrigerant in the system is recharged.

22. If the program had NOT been available, how likely would you have been to have maintenance/tune-up services performed on your HVAC system at your own expense?
23. Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely
    Don't know

24. If the program had NOT been available, when would you have taken on this project…?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don't know

25. [IF Q23 = Q23.A2] Please specify the number of months.
    [RECORD #]:

26. Which maintenance/tune-up equipment and services, if any, would you have completed without the program? Please select all that apply. [PRESENT ONLY MEASURES APPLICABLE HIDE/SHOW]
    HVAC Maintenance Assessment
    HVAC Coil Cleaning
    HVAC Duct Sealing
    HVAC Refrigerant Charge Adjustment
    Don't know

1.6 HVAC DUCT TEST AND SEAL FREE RIDER MODULE

[SKIP IF NO DUCT TEST AND SEAL MEASURES INSTALLED]

Duct sealing: In houses with forced-air heating and cooling systems, ducts distribute conditioned air throughout the house. In a typical house, however, about 20 to 30 percent of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts. Through duct sealing this air loss is reduced.

For this next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician conduct <u>Duct Testing and Sealing</u> on the air conditioning unit.

27. The Duct Test work perfomed on your homes heating/cooling system cost approximately $100-$300 to complete. Without the program, how likely would you have been to have this work done at your own expense? Would you say…?
    Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely
    Don't know

28. If the program had NOT been available, would you have taken on this project…?

At the same time or sooner
1 to 24 months later
More than 24 months later
Never
Don't know

29. Without the program, when do you think you would have had the Duct Test and Seal work performed?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don't know

30. [IF Q28 = Q28.A2] Please specify the number of months.
    [RECORD #]:

1.7 HVAC INDOOR FAN MOTOR CONTROLLER FREE RIDER MODULE

[SKIP IF NO INDOOR FAN MONTOR CONTROLLERS MEASURES INSTALLED]

For these next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician install the <u>Indoor Fan Motor Controller</u> on the air conditioning unit.

31. The High Efficiency Indoor Fan Motor Controller you installed through the program cost $120 to $150 more than the Standard Effiiciency option. Without the program, how likely would you have been to select and install a High Efficiency Indoor Fan Motor Controller at your own expense? Would you say…?
    Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely
    Don't know

32. Without the program, when do you think you would have had the Indoor Fan Motor Controller installed?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don't know

33. [IF Q31 = Q31.A2] Please specify the number of months.
    [RECORD #]:

1.8 HVAC INDOOR (FURNACE) MOTOR REPLACEMENT FREE RIDER MODULE

[SKIP IF NO HVAC MOTOR REPLACEMENT MEASURES INSTALLED]

For the next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician install a new Indoor Fan Motor on the furnace (heating) unit.

34. The High Efficiency fan motor you installed through the program cost $90 to $150 more than a Standard Efficiency fan motor. Without the program, how likely would you have been to select and install a High Efficiency fan motor at your own expense? Would you say…?
    - Very likely
    - Somewhat likely
    - A 50/50 chance
    - Somewhat unlikely
    - Very unlikely
    - Don't know

35. If the program had NOT been available, would you have taken on this project…?
    - At the same time or sooner
    - 1 to 24 months later
    - More than 24 months later
    - Never
    - Don't know

36. [IF Q34 = Q34.A2] Please specify the number of months.
    [RECORD #]:

37. Without the program, which of the following would you have done?
    - Nothing, no replacement or repair
    - Repair the existing equipment
    - Replace with a standard motor
    - Replace with a high efficiency motor (i.e. brushless)
    - Other (specify)
    - Don't know

1.9 FURNACE FREE RIDER MODULE

[SKIP IF NO FURNACE MEASURES INSTALLED]

For the next set of questions, we would like to know about the role the program had on your decision to install the high efficiency heating equipment (furnace). Please consider your decision to install a high efficiency furnace as opposed to standard efficiency furnace.

38. The High Efficiency furnace you installed through the program cost $100 to $1,200 more than a Standard Efficiency furnace. Without the program, how likely would you have been to select and install a High Efficiency furnace at your own expense? Would you say…?
    - Very likely
    - Somewhat likely
    - A 50/50 chance
    - Somewhat unlikely
    - Very unlikely
    - Don't know

39. Without the program(s), would you have installed a furnace at a level of efficiency that was…?
    - Same or higher than program requirements (95% or higher AFUE)
    - Slightly lower than required by program (91 to 94% AFUE)
    - Higher than allowable minimum (86 to 90% AFUE)
    - Slightly higher than allowable minimum (81 to 85% AFUE)
    - Minimum allowable efficiency (80% AFUE)

Would not have installed a furnace
Don’t know

1.10 HVAC / THERMOSTAT SET-UP

40. Does your home have multiple thermostats to control heat/cooling in different spaces?
    Yes
    No > *GoTo Q41*
    Don’t know > *GoTo Q41*

41. Without the program, how many smart thermostats would you have installed?
    None
    1
    2
    3
    4 or more
    Don’t know

[SKIP TO Q46 IF NO SMART THERMOSTAT MEASURES INSTALLED]

Your Previous Thermostat Use

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

43. [Skip if Q46 = “No thermostat”] How did you use your previous thermostat? Please select all that apply.
    Set a temperature and leave it alone (exclusive)
    Use a programmed schedule but may override to adjust to meet my comfort (programmable or smart t-stat only)
    Use a programmed schedule and rarely override (programmable or smart t-stat only)
    Turn the thermostat down or up at night
    Turn the thermostat off at night
    Turn the thermostat off when home is unoccupied
    None of these
    Don't recall

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

45. Do you use a mobile app to access your smart thermostat?
    Yes
    No > *GoTo Q46*

46. Which of the following smart thermostat mobile app features do you use? Please select all that apply.
    Remotely lock thermostat use

Remotely adjust home temperature
Pre-cool or pre-heat the home to an exact specified time (e.g., use the "Early On" feature)
Use an "Auto Away" feature, where the set point will automatically revert to the set-back temperature if the sensor senses no activity
Learn more about saving offers from [PA]
Other, specify:

Thermostat Set Points

AIR CONDITIONING COOLING SEASON OPERATION

We would like to know about your household's typical air conditioning and heating settings. When answering the following questions, please consider to the best of your ability your usage for 2019 as this is the period we are researching.

47. What months of the year do you typically have your thermostat set to "Cool" operation mode?
    - Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec (Check all that apply)
    - Cool always on (exclusive)
    - Cool always off (exclusive)
    - N/A do not have A/C (exclusive)

48. During the <u>hottest</u> part of the day, what is the typical cooling temperature setpoint? [Pick one]
    - Provide 2-degree ranges => Below 70, 70-71, 72-73, 74-75, 76-77, 78-79, 80-81, 82-83, 84-85, Above 85
    - Off
    - Don't know
    - Other (allow open ended) ___________

49. During <u>other times</u> of the day, when temperatures are milder, what is the typical cooling temperature setpoint? [Pick one]
    - Provide 2-degree ranges to reflect setup => Below 70, 70-71, 72-73, 74-75, 76-77, 78-79, 80-81, 82-83, 84-85, Above 85
    - Off
    - Don't know
    - Other (allow open ended) ___________

HEATING SEASON OPERATION

50. What months of the year do you typically have your thermostat set to "Heat" operation mode?
    - Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec (Please select all that apply)
    - Heat Always on (exclusive)
    - Heat Always off (exclusive)
    - N/A do not have a heating system (exclusive)
    - Off
    - Don't know

51. When occupants are awake and active and heating is needed, what is the typical heating temperature setpoint?
    - Provide 2-degree ranges => Below 54, 54-55, 56-57, 58-59, 60-61, 62-63, 64-65, 66-67, 68-69, 70-71, 72-73, 74-75, 76-77, 78-79, Above 80
    - Other (allow open ended) ___________

52. When heating is not needed as much or if a setback temperature is used at night, what is the typical heating temperature setpoint?

- Provide 2-degree ranges => Below 54, 54-55, 56-57, 58-59, 60-61, 62-63, 64-65, 66-67, 68-69, 70-71, 72-73, 74-75, 76-77, 78-79, Above 80
- OFF
- Other (allow open ended) ___________

1.11 SMART THERMOSTAT COMFORT & SATISFACTION

[SKIP TO Q55 IF NO SMART THERMOSTAT MEASURES WERE INSTALLED]

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

54. Overall, how satisfied are you with the smart thermostat you received through [PA]'s program?
    Very unsatisfied
    Somewhat unsatisfied
    Neutral
    Somewhat satisfied
    Very satisfied

55. Why do you give that rating?

1.12 TECHNOLOGY USE

56. Has your household enrolled in a [PA] Demand Response program since installing the smart thermostat?
    Yes
    No
    Don't know

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

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

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

1.13 HOUSEHOLD INFORMATION / DEMOGRAPHICS

58. Do you own or rent your current residence?
    Own

Rent

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

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

61. Which of the following best describes the main heating/cooling system in your home?

Note: In houses with forced-air heating and cooling systems, “central” ducts are used to distribute conditioned (hot or cold) air throughout the house.

Heating only
Central gas heater furnace, no air conditioning
Central propane furnace, no air conditioning
Central electric furnace, no air conditioning
Central heating (unsure of system type), no air conditioning

Heating with cooling
Central gas heater furnace with air conditioning
Central propane furnace with air conditioning
Central electric furnace with air conditioning
Central heating (unsure of system type) with air conditioning

Other
Central heat pump (cooling and heating)
Central AC and non-furnace heating (only AC is controlled by smart thermostat)
Other cooling and/or heating system (please describe)

62. [SKIP IF NO INDOOR FAN MOTOR CONTROLLER MEASURES INSTALLED] Approximately how old is your furnace?
0 to 5 years
6 to 10 years
11 to 15 years
16 or more
Don’t know

63. [SKIP IF NO FURNACE OR MOTOR REPLACEMENT MEASURES INSTALLED] What was the condition of your heating and cooling equipment when you replaced it?
Not working
Working, but some issues (i.e. need to be fixed / repaired)
Working
Other (specify)
Don’t know

64. Which of the following changes, if any, have you made in your home since 2019? Please select all changes that apply, or if none, please scroll down and select "no changes made".
Increased living area/square footage of your home (finished basement to add media room or bedroom, for example)
Decreased living area/square footage of your home (converted a bedroom to a storeroom, for example)
Using more lighting
Using less lighting
Using an additional refrigerator
Got rid of/recycled/stopped using an additional refrigerator
Added a pool
Eliminated/stopped using your pool
Added electric vehicle charging to the home
No longer charge electric vehicle at the home
Added a spa
Eliminated/stopped using your spa
Household size increased
Household size decreased
Replaced heating or cooling unit

Added heating or cooling unit
No changes

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

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

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

67. This information is collected for internal purposes only and remains confidential. Please check the range that best describes your household's total annual income.
    Less than $10,000
    $10,000 – $19,999
    $20,000 – $24,999
    $25,000 – $49,999
    $50,000 – $74,999
    $75,000 – $99,999
    $100,000 – $149,999
    $150,000 – $174,999
    $175,000 – $199,999
    $200,000 – $249,999
    $250,000 or more
    Prefer not to say

68. What is the highest degree or level of school you have completed? If you're currently enrolled in school, please indicate the highest degree you have received.
    Less than a high school diploma
    High school degree or equivalent
    Bachelor's degree (e.g. BA, BS)
    Master's degree (e.g. MA, MS, MEd)
    Doctorate (e.g. PhD, MD, EdD)
    Other (please specify)
    Prefer not to say

In order to ensure that energy efficiency programs serve all customer segments fairly, we would like to learn more about your household demographics.

69. What is the primary household language?
    English
    Spanish
    Chinese (including Mandarin and Cantonese)
    Tagalog
    Vietnamese
    Korean

Other (please specify)
Prefer not to say

70. Are you of Hispanic, Latino, or Spanish origin? Please select all that apply.
    - No, not of Hispanic, Latino, or Spanish origin
    - Yes, Mexican, Mexican American, Chicano
    - Yes, Puerto Rican
    - Yes, Cuban
    - Yes, another Hispanic, Latino, or Spanish origin (please specify)
    - Prefer not to say

71. What is your race?
    - White
    - Black or African American
    - American Indian or Alaska Native
    - Chinese
    - Asian Indian
    - Japanese
    - Korean
    - Filipino
    - Vietnamese
    - Other Asian
    - Pacific Islander
    - Some Other Race (please specify)
    - Prefer not to say

6.9 Appendix I: Multifamily property-manager phone survey

CPUC PY2019 Residential Combined (HVAC/RES)

Participant Online Survey

The combined HVAC and Res RoadMap Measure Groups captured in this survey are as follows:

IMPORT DATA FIELDS

- [SITE ID]
- [PA]
- [PROGRAM NAME]
- [INSTALL DATE]
- [CONTRACTOR NAME FOR DI MEASURES]
- [STREET ADDRESS, CITY]
- [YEAR INSTALLED] > EXCLUDE IF ALL = 2019
- TOTAL MEASURE COUNT
- MEASURE NAMES a-h (As shown in table, in individual columns)

Measure Group & Counts
(Section 1.4) SMART THERMOSTAT TYPE
(Section 1.5) HVAC MAINTENANCE ASSESSMENT (DESCRIBE)
(Section 1.5) HVAC COIL CLEANING
(Section 1.5) HVAC REFRIGERANT CHARGE ADJUSTMENT
(Section 1.6) HVAC DUCT TEST & SEAL
(Section 1.7) HVAC INDOOR FAN CONTROLER
(Section 1.8) HVAC INDOOR FAN MOTOR REPLACEMENT
(Section 1.9) HVAC FURNACE (DESCRIBE)

- Measure count (individual)
- Summary level (if >1) [Low end package cost] to [High end package cost]
- COMBINED MEASURE LIST WITH COMMA SEPERATOR (see Q22)
- SAMPLE WAVE COUNT

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

From: [PAs]

“SCE Energy Efficiency Evaluation"<donotreply_survey@sce.com>

“PG&E Energy Efficiency Evaluation"<feedback@survey.pge.com>

“SoCalGas Energy Efficiency Evaluation"<donotreply@survey.socalgas.com>

“SDG&E Energy Efficiency Evaluation"<donotreply@survey.sdge.com>

Subject line: Tell us about your experience with your [PA] sponsored HVAC energy efficient progam

---

Dear [PA] Customer,

Would you be one of the respondents who will help us meet our survey completion goals today? We need customers like you to provide us with feedback regarding your experience with your [PA] sponsored Smart Thermostat and/or HVAC equipment and services program. As a participant in [PA]'s program, your opinions are important. [PA] and the California Public Utilities Commission (CPUC) would like your input and perspectives to understand how to best structure future energy efficiency programs.

We’re requesting your participation today in a 15-minute survey. To thank you for your participation your household will be entered in a drawing for a $100 incentive. The information gathered will be used solely for research purposes and your individual responses will be kept confidential.

To get started click on this link: [ST]:

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

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

Peng Gong/Peter Franzese
California Public Utilities Commission
505 Van Ness Ave.
San Francisco, CA 94102

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

1.1 Online Survey – Introduction Page

Smart Thermostat / HVAC Survey

Survey Instructions

Hello,

This 15-minute survey is being conducted by an independent research organization with households that participated in the [PA] sponsored [PROGRAM_NAME] program to install energy efficiency equipment and services.

While completing the survey, please provide responses that reflect not just yourself but rather all household members that share the same electric bill. Do your best to answer all questions.

This study is sponsored by the California Public Utilities Commission (CPUC) and will be used to help plan programs to benefit homeowners and save energy. Responses to this survey will be kept strictly confidential and reported only in the aggregate.

Need Help? DNV GL has been hired to manage this study supported by [PA] and the California Public Utilities Commission. DNV GL support representatives can be reached by emailing us at: support@impact.dnvgl.com

1.2 INTRODUCTION

Screener: we are conducting research to learn more about your decision to install a variety of HVAC improvements in the air conditioning systems of **[NUMBER]** units you managed in 2019. These installations were done with help from a **[UTILITY]** energy efficiency program.

All of your responses will be treated confidentially.

Screener: Do you currently have active accounts with [PA] at this address: [Q1]?
Yes (Continue)
No (Thank and terminate)

1. [Deleted from MF PM interview]

2. According to [PA]'s records, in 2019 one or more of the following heating/cooling (HVAC) related improvements were made to units in the facility you manage. Are you aware of these equipment/service(s) upgrades? Select all that apply: [TABLE ONLY POPULATED WITH MEASURES THAT HAVE UNIT COUNT >0; 'Number of units' POPULATED FROM TRACKING DATA IF RESPONDENT RESPONDS 'Yes' TO AWARNESS QUESTION; FOR HVAC MAINTENANCE MEASURES, 'Number of units' = 'Number of systems' REPORTED IN Q1 DUE TO ORIGINAL UNITS BEING REPORTED IN CAP/TON]

Equipment and Services	Aware of installation? (Yes/No/Don't know)	Number of units installed/ serviced	Total Number of Units at Property	Are the number of units correct? (Yes/No/Don't know)	[IF NO] Please record correct quantity (record '0' if

					no measures installed)
1a. SMART THERMOSTAT					
1b. HVAC MAINTENANCE ASSESSMENT					
1c. HVAC COIL CLEANING					
1d. HVAC REFRIGERANT CHARGE ADJUSTMENT					
1e. HVAC DUCT SEALING					
1f. HVAC INDOOR FAN MOTOR CONTROLLER					
1g. HVAC INDOOR MOTOR REPLACEMENT					
1h. FURNACE					

[IF ALL Q1 Awareness = Don't Know]

3. Who do you suggest I speak with that would be familiar with this purchase decision?
   [RECORD] First and last name:
   [RECORD] Phone number:
   [RECORD] Email address:

   [THANK AND TERMINATE]

4. Which of the following factors influenced your decision to make these upgrades to your heating/cooling systems? Please select all that apply.
   Utility rebate / discount
   Utility offering was either low or no cost to me
   HVAC contractor recommendation
   Reduced my energy bills
   Non-energy impacts (e.g. improve comfort)
   Reduced carbon emissions / climate change
   Family/friend/neighbor recommendation
   Equipment failure or end of useful life
   Equipment needed maintenance
   Ease of use (e.g., smart thermostat)
   Good for the environment
   Other (please specify)
   Don't know (exclusive)

5. [SKIP IF ONLY 1 MEASURE INSTALLED IN Q2] [PA]'s records show your facility had the following HVAC upgrades made to your home [REPEAT LIST FROM TABLE ABOVE HERE]. When thinking about the decision to have these upgrades performed how did you approach the project?
   I thought of all the equipment and services installed as a PACKAGE > *GoTo Q6*
   I thought of each piece of equipment and service individually > *GoTo Q15*
   Don't know > *GoTo Q3*

1.3 OVERALL FREE RIDER MODULE

In this survey, we would like to learn about the role of [PA]'s program in your decision-making process to go ahead with this/these HVAC upgrades. [PA]'s program offering may have included a free or lower-cost thermostat, HVAC service(s) such as a tune-up for a heater or air conditioner, and/or upgrades like a new motor or a rebate for a high efficiency furnace. The offering may have been discounted through a rebate or provided at no cost if your income qualified.

6. Without [PA]'s program offering (rebate/service), how likely would you have been to initiate and complete the entire project at full price? Would you say…
   Very likely
   Somewhat likely
   A 50/50 chance
   Somewhat unlikely
   Very unlikely
   Don't know

7. [SKIP IF ONLY FURNACE MEASURE INSTALLED] Without [PA]'s program offering in 2019, when would you have completed these projects?
   At the same time or sooner
   1 to 24 months later
   More than 24 months later
   Never
   Don't know

8. [IF Q7 = Q7.A2] Please specify the number of months:
   [RECORD #]:

9. Without [PA]'s program offering, which of the following equipment and/or services **would you have completed at the property owner's expense**? Please select all that apply. ['Number of units' UPDATED BASED ON RESPONSE TO Q1; HIDE ROWS THAT ARE NOT APPLICABLE]

Equipment and Services	Number of Units Upgraded	Total Number of Units
1a. SMART THERMOSTAT		
1b. HVAC MAINTENANCE ASSESSMENT		
1c. HVAC COIL CLEANING		
1d. HVAC REFRIGERANT CHARGE ADJUSTMENT		
1e. HVAC DUCT SEALING		
1f. HVAC INDOOR FAN MOTOR CONTROLLER		
1g. HVAC INDOOR FAN MOTOR REPLACEMENT		
1h. FURNACE		
NONE OF THESE (exclusive)		
ALL OF THESE (exclusive)		

10. [SKIP IF Q9 ≠ "NONE OF THESE"] Why wouldn't you have completed any part of this project? Please select all that apply.
    Unaware it needed to be done
    Not a priority
    Cost to upgrade/too expensive
    Not responsible to maintain equipment
    Difficult to find a qualified contractor
    Unsure that energy savings are worth the cost
    Don't know (exclusive)
    Other

11. [SKIP IF Q9 = "NONE OF THESE"] Why would you have completed some or all of the project without [PA]'s program offering (incentives/services)? Please select all that apply.
    - Save money/energy
    - Equipment failure or end of useful life
    - Health and safety
    - Improve comfort
    - Remodel or renovation
    - Recommendation from a contractor
    - Good for the environment
    - Appeal to prospective or current renters
    - Ease of use
    - Don't know (exclusive)
    - Other

12. [SKIP IF NO SMART THERMOSTAT MEASURES INSTALLED] Smart thermostats come in a variety of models. There are BASIC models that cost about $150-$200 (e.g., Nest E and Ecobee 3 lite) and UPGRADED models that cost about $250-$300 which offer additional sensing technology (e.g., Nest Learning 3rd Gen and Ecobee 4).

    If the program didn't offer a smart thermostat rebate in 2019, which model would you have likely purchased?
    - Would have purchased the BASIC model smart thermostat
    - Would have purchased the UPGRADED model smart thermostat
    - Would have purchased a standard programmable thermostat (e.g., without smart capabilities)
    - Would NOT have purchased a thermostat at all

13. [SKIP IF NO FURNACE MEASURES INSTALLED] Without the program(s), would you have installed a furnace at a level of efficiency that was…?
    - Same or higher than program requirements (95% or higher AFUE)
    - Slightly lower than required by program (91 to 94% AFUE)
    - Higher than allowable minimum (86 to 90% AFUE)
    - Slightly higher than allowable minimum (81 to 85% AFUE)
    - Minimum allowable efficiency (80% AFUE)
    - Would not have installed a furnace
    - Don't know

14. [SKIP IF NO MOTOR REPLACEMENT MEASURES INSTALLED] We would also like to know what influence the program had (if any) on the decision to have an HVAC technician install a new Fan Motor on the air conditioning unit. Without the program, which of the following would you have done?
    - Nothing, no replacement or repair
    - Repair the existing equipment
    - Replace with a standard motor
    - Replace with a high efficiency motor (i.e. brushless)
    - Other (specify)
    - Don't know

[SKIP TO Q39, SECTION 1.10]

1.4 SMART THERMOSTAT FREE RIDER MODULE

[SKIP IF NO SMART THERMOSTAT MEASURES INSTALLED]

First, we would like to know about the smart thermostat provided or rebated by the program.

15. Is the smart thermostat still in place and operational in your home?
    Yes [GOTO Q17]
    No > *[Goto Q16]*

16. Why was the thermostat removed/non-operational? [GOTO Q22]

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

For this next set of questions, we would like to know about your decision to install the smart thermostat and the role the [PA]'s **rebate program had (if any).**

18. What is the likelihood you would have purchased the same smart thermostat, if the rebate was not available?
    Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely

19. If the program didn't offer a rebate for this smart thermostat in 2019, when would you have purchased it…?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don't know

20. [IF Q19 = Q19.A2] Please specify the number of months:
    [RECORD #]:

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

    If the program didn't offer a smart thermostat rebate in 2019, which model would you have likely purchased?

    Would have purchased the BASIC model smart thermostat
    Would have purchased the UPGRADED model smart thermostat
    Would have purchased a standard programmable thermostat (e.g., without smart capabilities)
    Would NOT have purchased a thermostat at all

1.5 HVAC ASSESSMENT, MAINTENANCE, AND REPAIR FREE RIDER MODULE

[SKIP IF NO COIL CLEANING, RCA, MAINTENANCE MEASURES INSTALLED]

For these next set of questions, we would like to know how your decision to have <u>HVAC assessment, maintenance, and repairs</u> performed may have changed in the absence of the program incentive or no cost service.**

Coil cleaning: A maintenance process performed by a HVAC service technician, whereby the outdoor air conditioning unit's condenser coils are cleaned of debris. This process can help improve the efficiency of your air conditioning unit.

Refrigerant charge adjustment: A maintenance process performed by a HVAC service technician, whereby the refrigerant in the system is recharged.

22. If the program had NOT been available, how likely would you have been to have maintenance/tune-up services performed on your HVAC system at your own expense?
23. Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely
    Don't know

24. If the program had NOT been available, when would you have taken on this project…?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don't know

25. [IF Q23 = Q23.A2] Please specify the number of months.
    [RECORD #]:

26. Which maintenance/tune-up equipment and services, if any, would you have completed without the program? Please select all that apply. [PRESENT ONLY MEASURES APPLICABLE HIDE/SHOW]
    HVAC Maintenance Assessment
    HVAC Coil Cleaning
    HVAC Duct Sealing
    HVAC Refrigerant Charge Adjustment
    Don't know

1.6 HVAC DUCT TEST AND SEAL FREE RIDER MODULE

[SKIP IF NO DUCT TEST AND SEAL MEASURES INSTALLED]

Duct sealing: In houses with forced-air heating and cooling systems, ducts distribute conditioned air throughout the house. In a typical house, however, about 20 to 30 percent of the air that moves through the duct system is lost due to leaks, holes, and poorly connected ducts. Through duct sealing this air loss is reduced.

For this next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician conduct <u>Duct Testing and Sealing</u> on the air conditioning unit.

27. The Duct Test work perfomed on your homes heating/cooling system cost approximately $100-$300 to complete. Without the program, how likely would you have been to have this work done at your own expense? Would you say…?
    Very likely

Somewhat likely
A 50/50 chance
Somewhat unlikely
Very unlikely
Don’t know

28. If the program had NOT been available, would you have taken on this project…?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don’t know

29. Without the program, when do you think you would have had the Duct Test and Seal work performed?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don’t know

30. [IF Q28 = Q28.A2] Please specify the number of months.
    [RECORD #]:

1.7 HVAC INDOOR FAN MOTOR CONTROLLER FREE RIDER MODULE

[SKIP IF NO INDOOR FAN MONTOR CONTROLLERS MEASURES INSTALLED]

For these next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician install the <u>Indoor Fan Motor Controller</u> on the air conditioning unit.

31. The High Efficiency Indoor Fan Motor Controller you installed through the program cost $120 to $150 more than the Standard Effiiciency option. Without the program, how likely would you have been to select and install a High Efficiency Indoor Fan Motor Controller at your own expense? Would you say…?
    Very likely
    Somewhat likely
    A 50/50 chance
    Somewhat unlikely
    Very unlikely
    Don’t know

32. Without the program, when do you think you would have had the Indoor Fan Motor Controller installed?
    At the same time or sooner
    1 to 24 months later
    More than 24 months later
    Never
    Don’t know

33. [IF Q31 = Q31.A2] Please specify the number of months.
    [RECORD #]:

1.8 HVAC INDOOR (FURNACE) MOTOR REPLACEMENT FREE RIDER MODULE

[SKIP IF NO HVAC MOTOR REPLACEMENT MEASURES INSTALLED]

For the next set of questions, we would like to know about the program influence (if any) on the decision to have an HVAC technician install a new Indoor Fan Motor on the furnace (heating) unit.

34. The High Efficiency fan motor you installed through the program cost $90 to $150 more than a Standard Efficiency fan motor. Without the program, how likely would you have been to select and install a High Efficiency fan motor at your own expense? Would you say…?
    - Very likely
    - Somewhat likely
    - A 50/50 chance
    - Somewhat unlikely
    - Very unlikely
    - Don't know

35. If the program had NOT been available, would you have taken on this project…?
    - At the same time or sooner
    - 1 to 24 months later
    - More than 24 months later
    - Never
    - Don't know

36. [IF Q34 = Q34.A2] Please specify the number of months.
    [RECORD #]:

37. Without the program, which of the following would you have done?
    - Nothing, no replacement or repair
    - Repair the existing equipment
    - Replace with a standard motor
    - Replace with a high efficiency motor (i.e. brushless)
    - Other (specify)
    - Don't know

1.9 FURNACE FREE RIDER MODULE

[SKIP IF NO FURNACE MEASURES INSTALLED]

For the next set of questions, we would like to know about the role the program had on your decision to install the high efficiency heating equipment (furnace). Please consider your decision to install a high efficiency furnace as opposed to standard efficiency furnace.

38. The High Efficiency furnace you installed through the program cost $100 to $1,200 more than a Standard Efficiency furnace. Without the program, how likely would you have been to select and install a High Efficiency furnace at your own expense? Would you say…?
    - Very likely
    - Somewhat likely
    - A 50/50 chance
    - Somewhat unlikely
    - Very unlikely
    - Don't know

39. Without the program(s), would you have installed a furnace at a level of efficiency that was…?
    - Same or higher than program requirements (95% or higher AFUE)
    - Slightly lower than required by program (91 to 94% AFUE)
    - Higher than allowable minimum (86 to 90% AFUE)
    - Slightly higher than allowable minimum (81 to 85% AFUE)
    - Minimum allowable efficiency (80% AFUE)
    - Would not have installed a furnace
    - Don't know

1.10 HVAC / THERMOSTAT SET-UP

40. Does your home have multiple thermostats to control heat/cooling in different spaces?
    - Yes
    - No > *GoTo Q41*
    - Don't know > *GoTo Q41*

41. Without the program, how many smart thermostats would you have installed?
    - None
    - 1
    - 2
    - 3
    - 4 or more
    - Don't know

[SKIP TO Q46 IF NO SMART THERMOSTAT MEASURES INSTALLED]

Your Previous Thermostat Use

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

43. [Skip if Q46 = "No thermostat"] How did you use your previous thermostat? Please select all that apply.
    - Set a temperature and leave it alone (exclusive)
    - Use a programmed schedule but may override to adjust to meet my comfort (programmable or smart t-stat only)
    - Use a programmed schedule and rarely override (programmable or smart t-stat only)
    - Turn the thermostat down or up at night
    - Turn the thermostat off at night
    - Turn the thermostat off when home is unoccupied
    - None of these
    - Don't recall

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

45. Do you use a mobile app to access your smart thermostat?

Yes
No > *GoTo Q46*

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

Thermostat Set Points

AIR CONDITIONING COOLING SEASON OPERATION

We would like to know about your household's typical air conditioning and heating settings. When answering the following questions, please consider to the best of your ability your usage for 2019 as this is the period we are researching.

47. What months of the year do you typically have your thermostat set to "Cool" operation mode?
    - Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec (Check all that apply)
    - Cool always on (exclusive)
    - Cool always off (exclusive)
    - N/A do not have A/C (exclusive)

48. During the <u>hottest</u> part of the day, what is the typical cooling temperature setpoint? [Pick one]
    - Provide 2-degree ranges => Below 70, 70-71, 72-73, 74-75, 76-77, 78-79, 80-81, 82-83, 84-85, Above 85
    - Off
    - Don't know
    - Other (allow open ended) ___________

49. During <u>other times</u> of the day, when temperatures are milder, what is the typical cooling temperature setpoint? [Pick one]
    - Provide 2-degree ranges to reflect setup => Below 70, 70-71, 72-73, 74-75, 76-77, 78-79, 80-81, 82-83, 84-85, Above 85
    - Off
    - Don't know
    - Other (allow open ended) ___________

HEATING SEASON OPERATION

50. What months of the year do you typically have your thermostat set to "Heat" operation mode?
    - Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec (Please select all that apply)
    - Heat Always on (exclusive)
    - Heat Always off (exclusive)
    - N/A do not have a heating system (exclusive)
    - Off
    - Don't know

51. When occupants are awake and active and heating is needed, what is the typical heating temperature setpoint?

- Provide 2-degree ranges => Below 54, 54-55, 56-57, 58-59, 60-61, 62-63, 64-65, 66-67, 68-69, 70-71, 72-73, 74-75, 76-77, 78-79, Above 80
- Other (allow open ended) ___________

52. When heating is not needed as much or if a setback temperature is used at night, what is the typical heating temperature setpoint?
    - Provide 2-degree ranges => Below 54, 54-55, 56-57, 58-59, 60-61, 62-63, 64-65, 66-67, 68-69, 70-71, 72-73, 74-75, 76-77, 78-79, Above 80
    - OFF
    - Other (allow open ended) ___________

1.11 SMART THERMOSTAT COMFORT & SATISFACTION

[SKIP TO Q55 IF NO SMART THERMOSTAT MEASURES WERE INSTALLED]

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

54. Overall, how satisfied are you with the smart thermostat you received through [PA]'s program?
    Very unsatisfied
    Somewhat unsatisfied
    Neutral
    Somewhat satisfied
    Very satisfied

55. Why do you give that rating?

1.12 TECHNOLOGY USE

56. Has your household enrolled in a [PA] Demand Response program since installing the smart thermostat?
    Yes
    No
    Don't know

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

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

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

1.13 HOUSEHOLD INFORMATION / DEMOGRAPHICS

58. Do you own or rent your current residence?
    - Own
    - Rent

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

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

61. Which of the following best describes the main heating/cooling system in your home?

Note: In houses with forced-air heating and cooling systems, "central" ducts are used to distribute conditioned (hot or cold) air throughout the house.

Heating only
Central gas heater furnace, no air conditioning
Central propane furnace, no air conditioning
Central electric furnace, no air conditioning
Central heating (unsure of system type), no air conditioning

Heating with cooling
Central gas heater furnace with air conditioning
Central propane furnace with air conditioning
Central electric furnace with air conditioning
Central heating (unsure of system type) with air conditioning

Other
Central heat pump (cooling and heating)
Central AC and non-furnace heating (only AC is controlled by smart thermostat)
Other cooling and/or heating system (please describe)

62. [SKIP IF NO INDOOR FAN MOTOR CONTROLLER MEASURES INSTALLED] Approximately how old is your furnace?
0 to 5 years
6 to 10 years
11 to 15 years
16 or more
Don't know

63. [SKIP IF NO FURNACE OR MOTOR REPLACEMENT MEASURES INSTALLED] What was the condition of your heating and cooling equipment when you replaced it?
Not working
Working, but some issues (i.e. need to be fixed / repaired)
Working
Other (specify)
Don't know

64. Which of the following changes, if any, have you made in your home since 2019? Please select all changes that apply, or if none, please scroll down and select "no changes made".
Increased living area/square footage of your home (finished basement to add media room or bedroom, for example)
Decreased living area/square footage of your home (converted a bedroom to a storeroom, for example)
Using more lighting
Using less lighting
Using an additional refrigerator
Got rid of/recycled/stopped using an additional refrigerator
Added a pool
Eliminated/stopped using your pool
Added electric vehicle charging to the home
No longer charge electric vehicle at the home
Added a spa
Eliminated/stopped using your spa
Household size increased
Household size decreased
Replaced heating or cooling unit

Added heating or cooling unit
No changes

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

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

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

67. This information is collected for internal purposes only and remains confidential. Please check the range that best describes your household's total annual income.
Less than $10,000
$10,000 – $19,999
$20,000 – $24,999
$25,000 – $49,999
$50,000 – $74,999
$75,000 – $99,999
$100,000 – $149,999
$150,000 – $174,999
$175,000 – $199,999
$200,000 – $249,999
$250,000 or more
Prefer not to say

68. What is the highest degree or level of school you have completed? If you're currently enrolled in school, please indicate the highest degree you have received.
Less than a high school diploma
High school degree or equivalent
Bachelor's degree (e.g. BA, BS)
Master's degree (e.g. MA, MS, MEd)
Doctorate (e.g. PhD, MD, EdD)
Other (please specify)
Prefer not to say

In order to ensure that energy efficiency programs serve all customer segments fairly, we would like to learn more about your household demographics.

69. What is the primary household language?
English
Spanish
Chinese (including Mandarin and Cantonese)
Tagalog
Vietnamese
Korean

Other (please specify)
Prefer not to say

70. Are you of Hispanic, Latino, or Spanish origin? Please select all that apply.
    - No, not of Hispanic, Latino, or Spanish origin
    - Yes, Mexican, Mexican American, Chicano
    - Yes, Puerto Rican
    - Yes, Cuban
    - Yes, another Hispanic, Latino, or Spanish origin (please specify)
    - Prefer not to say

71. What is your race?
    - White
    - Black or African American
    - American Indian or Alaska Native
    - Chinese
    - Asian Indian
    - Japanese
    - Korean
    - Filipino
    - Vietnamese
    - Other Asian
    - Pacific Islander
    - Some Other Race (please specify)
    - Prefer not to say

6.10 Appendix J: Upstream distributor/manufacturer (furnaces) survey

DNV·GL

CPUC HVAC PY2019 Net Furnace Distributor Survey

Introduction

Hello <Distributor Name>, this is <Interviewer name>. The reason for my call is I'm conducting a state-wide evaluation of the utility-sponsored Residential Furnace Distributor Rebate Programs. I'd like to ask you about your company's experience with this program. This call is sponsored by the CA Public Utilities Commission and performed here at DNV GL. (PAUSE). I'd like to assure you that I'm not selling anything and the information you provide is treated confidentially.

[AGREES TO PARTICIPATE]	1	SC1
[DOES NOT AGREE TO PARTICIPATE]	2	Thank & Terminate

[REPEAT IF NEEDED] All survey information collected including the results to this survey will be treated confidentially and reported only in aggregate form.

[IF ASKED] If you would like to verify the legitimacy of this research, our CPUC manager is Peng Gong and his phone number is 916-894-5636. If you have questions about this or the follow up survey, you can reach our study manager by calling Cameron Tuttle at (415) 706 - 4580.

Screener questions

SC1. The California Investor Owned Utilities SoCal Gas and San Diego Gas & Electric deliver incentives through residential HVAC upstream equipment incentive programs that buy down the cost of high-efficiency residential furnaces. The incentive records show your company received rebates. Are you familiar with your company's participation in this program?

Yes	1	G1
No	2	SC1a
Don't know	98	
Refused	99	

SC1a. Who at your company could I speak with that would be familiar with this program or your residential furnace sales?

Record name and contact details and ask to speak with them.	1	G1
No one	2	Terminate
Don't know	98	
Refused	99	

General distributor information

Next I'm going to ask a few general questions about your company.

G1. Which of the following distribution business models best describes your business model? Is your company a… [READ LIST; CHOOSE ALL THAT APPLY]

An Independent HVAC equipment distributor	1	G2
A manufacturer-owned or franchise distributor	2	
An Independent manufacturers' representative	3	
[Other (Self-report]	50/Record	

G2. Does the company also offer residential furnace installations?

Yes	1	G3
No	2	G4
Don't know	98	
Refused	99	

G3. Would you say the company is more of a distributor, installer, or manufacturer?

Distributor	1	D1
Installer	2	
Manufacturer	3	
Don't know	98	
Refused	99	

Distribution area

D1. Which regions in California do you distribute your furnaces? Do you sell in northern, central or southern California?

[Northern]	1	D1a
[Central]	2	
[Southern]	3	
[All of the Above]	4	
[Don't know]	98	D1b
[Refused]	99	

D1a. Which of those regions do you have personal knowledge of when it comes to sales and sales practices?

[Northern]	1	ME1
[Central]	2	
[Southern]	3	
[All of the Above]	4	
[Don't know]	98	D1b
[Refused]	99	

D1b. Is there anyone else at <company> who I could talk to that is knowledgeable about sales and sales practices in regions that you're not familiar with?

[Record verbatim] *[If "Yes", ask for contact info at the end of the interview]*		D4
Don't know	98	
Refused	99	

Market effects

Sales

ME1. What are the strongest drivers for high-efficiency furnace sales?
[PROMPT AS NEEDED, RECORD ALL THAT APPLY]

Sales engineers upselling practices	1	ME2
Available stock / delivery time	2	
ROI or payback calculations	3	
Engineer / Architect preferences	4	
Manufacturer rebates / promotions	5	
Utility rebates	6	
Non-rebate program activities (e.g. quarterly sales meeting, letter of commitment, market reports)	7	
Other (Record)	50	
Don't know	98	
Refused	99	

ME2. What are the biggest barriers when it comes to selling high-efficiency furnaces?
[PROMPT AS NEEDED, RECORD ALL THAT APPLY]

Increased cost of HE models	1	ME3
Increased size/weight of HE models	2	
Increased delivery time of HE models	3	
Market demand or turn over rate	4	
Sales marketing / educating buyers	5	
Ability to keep repairing old equipment	6	
Other (Record)	50	
Don't know	98	
Refused	99	

ME3. Which of the following non-rebate program activities has your company participated in or received from the program?
[PROMPT AS NEEDED, RECORD ALL THAT APPLY]

Letter of commitment to sell high efficiency equipment	1	ME3a
Regular meetings with program staff and your sales engineers	2	ME3a
Quarterly program market share report	3	ME3a

Other [SPECIFY]	4	ME3a
Don't know	98	ME3a
Refused	99	ME3a

ME3a. How, if at all, do the program rebates and non-rebate activities help you overcome the barriers to selling efficient furnace models?

[Record verbatim]		ME4
Don't know	98	ME4
Refused	99	ME4

ME4. What effects, if any, do the <PROGRAM> rebates and non-rebate activities have on your company's *policies* regarding stocking of high efficiency furnaces?

[Record verbatim]		ME5
Don't know	98	ME5
Refused	99	ME5

ME5. What effects, if any, do the <PROGRAM> rebates and non-rebate activities have on your company's *policies* regarding upselling of high efficiency furnaces?

[Record verbatim]		S1
Don't know	98	S1
Refused	99	S1

Stocking

Next, I would like to ask about your organization's residential furnace stocking practices.

S1. Does your company maintain a stock of high-efficiency furnaces? [Refer to the following table for a list of high-efficiency furnaces for this study]

Equipment Type	70% AFUE	92% AFUE	95% AFUE	96% AFUE	97% AFUE
High-efficiency Central Gas Furnace					
Gravity Wall Furnace					

Yes	1	S2
No	2	U1
Don't know	98	S2
Refused	99	U1

S2. How are stocking decisions made for high-efficiency furnaces?

[Record verbatim]		S3
Don't know	98	S3
Refused	99	U1

S3. How, if at all, do factors like equipment size and type affect your stocking decisions?

[Record verbatim]		S4
Don't know	98	
Refused	99	U1

S4. Are the inventories for high-efficiency furnaces relatively constant, or are there seasonal fluctuations? [SELECT ALL THAT APPLY]

Constant	1	S5
Seasonal variation	2	
[Varies by equipment type (record)]	3	
[Made to order]	4	
[Don't know]	98	
[Refused]	99	

S5. **What factors do you believe are the most influential in the stocking of your high-efficiency furnaces? [PROMPT AS NEEDED, RECORD ALL THAT APPLY]**

Utility rebates	1	S6
Market demand or turns rate	2	S6
Competitive comparisons/market competition	3	
Manufacturer rebates	4	
Energy costs	5	
Sales marketing/education	6	
Vendor promotions	7	
New product line offering	8	
Warehouse size limitations	9	
Other	50	
Don't know	98	
Refused	99	

S6. **Does the utility rebate influence the selection of high-efficiency furnaces the company keeps in stock?**

Yes	1	S7
No	2	
Don't know	98	S8
Refused	99	

S7. **Why do you say that?**

[Record verbatim]		S8
Don't know	98	
Refused	99	

[Question related to NTG calculations

S8. **For residential furnaces that you keep in stock, approximately what percent are high efficiency?** [IF NECESSARY: High-efficiency is defined as Tier 1 and above.]

[Record verbatim]	%	IF 0% or DK/R, GO TO U1; ELSE GO TO S9
Don't know	98	
Refused	99	

[IF 0%, DK/R, SKIP TO U1]

*[**Question related to NTG calculations***

Repeat for each equipment type and size confirmed as sold in questions D4-D7]

S9. If the program weren't available what percent of high efficiency [equipment type] [size] would you stock?

[Record verbatim]	%	U1
Don't know	98	
Refused	99	

Upselling

Now I want to talk about upselling.

U1. Please describe how you typically promote and sell high efficiency furnaces.

[Record verbatim]		
Don't know	98	U2
Refused	99	

U2. Does your company make furnace recommendations to contractors or other buyers?

Yes	1	U2a
No	2	
Don't know	98	P1
Refused	99	

U2a. What percent of the time does your company make any recommendation to buyers?

[Record %]		
Don't know	98	U3
Refused	99	

U2b. What information do you consider when you make recommendations?

[Record verbatim]		U2c
Don't know	98	U3
Refused	99	

U2c. How do you determine what efficiency level to recommend?

[Record verbatim]		
Don't know	98	U3
Refused	99	

U3. Does the Upstream rebate influence the equipment efficiency level your company recommends to furnace buyers?

Yes	1	U4
No	2	U4
Don't know	98	U5
Refused	99	

U4. Why do you say that?

[Record verbatim]		
Don't know	98	U5
Refused	99	

[Question related to NTG calculations

R

U5. In situations where you are selling residential furnaces, about what percent of the time do you recommend the high-efficiency models?

[IF NECESSARY: High-efficiency is defined as Tier 1 and above.]

[Record verbatim]	%	If 0% or DK/R GOTO P1 ELSE GOTO U6
Don't know	98	
Refused	99	

[Question related to NTG calculations

U6. For residential furnaces, what percent of the time would you recommend the high-efficiency equipment if [Program] did not exist? *[Probe: and what we mean by "without the program" is supposing the program ran out of funding next month]*

[IF NECESSARY: High-efficiency is defined as Tier 1 and above.]

[Record verbatim]	%	P1
Don't know	98	
Refused	99	

Trickle down incentives

P1. How does your company determine the price the buyer pays for the high-efficiency residential furnaces we've been discussing?

[Record verbatim]		P2
Don't know	98	
Refused	99	

P2. Is the price ever negotiable?

Yes	1	P3
No	2	
Don't know	98	
Refused	99	

P3. Does the rebate impact the final price paid by the buyer?

Yes	1	P3a
No	2	P3a
Don't know	98	Next Section
Refused	99	

P3a. Why do you say that?

[Record verbatim]		P4
Don't know	98	
Refused	99	

*[**Question related to NTG calculations***

Repeat for each equipment type and size confirmed as sold in questions D4-D7]

P4. On average, what percent of the rebate is passed on to the buyer for residential furnaces, either directly or indirectly?

[Record verbatim]	%	ME6
Don't know	98	
Refused	99	

Program influence on sales

[Question related to NTG calculations

[IF WE HAVE TOTAL REBATES CLAIMED BY DISTRIBUTOR FROM TRACKING DATA, SKIP TO ME10]

ME6. In 2019, about what percentage of residential furnaces that you sold in California would you estimate were high-efficiency, which is defined as Tier 1 and above?

[Record verbatim]	%	If 0% or DK/R GOTO PE1 ELSE GOTO ME7
Don't know	98	
Refused	99	

ME7. Without the program rebates and non-rebate activities, what percentage of your 2019 California residential furnace sales WOULD HAVE been high efficiency?
[IF NECESSARY: High efficiency means tier 1 or above]

[Record verbatim]	%	ME8
Don't know	98	
Refused	99	

ME8. What percent of all of your 2019 high-efficiency residential furnace sales had a rebate claimed?

[Record verbatim]	%	ME9
Don't know	98	
Refused	99	

ME9. [IF ANY ME6-ME8 >0] Why doesn't your company submit rebates for all the high-efficiency equipment types? [Reflect all that apply]

Not qualified	1	PE1
Missed opportunity	2	
Paid through down/mid-stream rebate	3	
Not in IOU service territory	4	
Other reason [Record Verbatim]	50	
Don't know	98	
Refused	99	

[IF WE HAVE TOTAL REBATES CLAIMED BY DISTRIBUTOR FROM TRACKING DATA, WE WILL ASK ME10 INSTEAD OF ME6 TO ME9]

ME10. I'm going to go through the number of rebates you claimed for residential furnaces in 2019. I'm assuming each one represents the sale of a high efficiency unit. I'd like you to estimate how many of those high efficiency sales would have still occurred without the program?
[IF NECESSARY: High efficiency means tier 1 and above]

# SOLD **Equipment Type/Size**	Number Sold	Number WOULD HAVE been sold
Residential Furnaces	PIPE IN	RECORD VERBATIM

Process questions

[Go through this section if you have time, and participant doesn't seem anxious to get off the phone. These questions are "nice to haves", not "must haves".]

PE1. Do you have any suggestions on how the program can be improved?

[Record verbatim]		PE2
Don't know	98	
Refused	99	

PE2. Is there anything else you would like to tell us regarding your experience with this program?

[Record verbatim]		End
Don't know	98	
Refused	99	

End. Those are all the questions I have for you today. Unless you have any questions for me, we are finished. Thank you for your time and cooperation.

6.11 Appendix K: Detailed savings estimates for frequent measure bundles

This section presents the detailed savings estimate by building type and measure bundle. We selected the climate zone with the highest number of households in the analysis by building type.

Table 6-3 provides electric savings for measures in bundles installed in at least 10 homes in climate zone 10 mobile homes.

Table 6-3. Electric savings by bundle for mobile home participants in climate zone 10

Measure Bundle	Fan motor replacement	Fan controls	Duct testing and sealing	Coil cleaning	Smart thermostat	Refrigerant charge adjustment	Households
Duct testing and sealing			127				58
Fan controls		76					14
Fan motor replacement	148						14
RCA						24	24
Smart thermostat					45		429
Coil cleaning, RCA				49		8	26
Duct testing and sealing, RCA			56			2	15
Duct testing and sealing, smart thermostat			66		9		92
Fan controls, duct testing and sealing		33	54				11
Fan controls, RCA		40				3	27
Fan controls, smart thermostat		45			9		109
Fan motor replacement, smart thermostat	73				8		68
Smart thermostat, RCA					22	7	37
Coil cleaning, smart thermostat, RCA				35	17	6	56
Duct testing and sealing, coil cleaning, RCA			102	28		4	64
Duct testing and sealing, smart thermostat, RCA			93		12	4	16
Fan controls, coil cleaning, RCA		77		34		6	16
Fan controls, duct testing and sealing, smart thermostat		57	93		12		36
Fan controls, smart thermostat, RCA		54			11	4	68
Fan motor replacement, duct testing and sealing, smart thermostat	117		97		13		10
Fan motor replacement, fan controls, smart thermostat	113	57			12		19
Duct testing and sealing, coil cleaning, smart thermostat, RCA			105	28	14	5	56
Fan controls, coil cleaning, smart thermostat, RCA		69		31	15	5	58
Fan controls, duct testing and sealing, coil cleaning, RCA		59	96	26		4	80

Measure Bundle	Fan motor replacement	Fan controls	Duct testing and sealing	Coil cleaning	Smart thermostat	Refrigerant charge adjustment	Households
Fan motor replacement, coil cleaning, smart thermostat, RCA	116			26	13	4	14
Fan motor replacement, fan controls, duct testing and sealing, smart thermostat	117	60	97		13		21
Fan controls, duct testing and sealing, coil cleaning, smart thermostat, RCA		59	97	26	13	4	161
Fan motor replacement, duct testing and sealing, coil cleaning, smart thermostat, RCA	120		100	27	13	4	11
Fan motor replacement, fan controls, coil cleaning, smart thermostat, RCA	107	55		24	12	4	23
Fan motor replacement, fan controls, duct testing and sealing, coil cleaning, RCA	104	53	87	23		4	24
Fan motor replacement, fan controls, duct testing and sealing, smart thermostat, RCA	96	49	80		10	4	12
Fan motor replacement, fan controls, duct testing and sealing, coil cleaning, smart thermostat, RCA	99	51	82	22	11	4	88

Table 6-4 provides electric savings for measures in bundles installed in at least 10 homes in climate zone 10 multifamily homes.

Table 6-4. Electric savings by bundle for multifamily participant homes in climate zone 10

Measure Bundle	Fan controls	Smart thermostat	Lighting	Households
Fan controls	78			14
Smart thermostat		69		6,069
Fan controls, smart thermostat	66	17		1,368
Smart thermostat, lighting		52	18	298
Fan controls, smart thermostat, lighting	63	16	13	392

Table 6-5 provides electric savings for measures in bundles installed in at least 10 homes in climate zone 13 single family homes.

Table 6-5. Electric savings by bundle for single family participant homes in climate zone 13

Measure Bundle	Fan motor replacement	Fan controls	Duct testing and sealing	Coil cleaning	Smart thermostat	Refrigerant charge adjustment	Lighting	Smart power strip	Households
Fan control		102							21
Fan motor replacement	165								208
Lighting							19		160

Measure Bundle	Fan motor replacement	Fan controls	Duct testing and sealing	Coil cleaning	Smart thermostat	Refrigerant charge adjustment	Lighting	Smart power strip	Households
Smart thermostat					27				33
Coil cleaning, RCA				44		7			104
Fan control, coil cleaning		84		37					468
Fan control, lighting		125					34		28
fan control, RCA		84				6			23
Fan control, smart thermostat		81			16				35
Fan motor replacement, coil cleaning	135			35					19
Fan motor replacement, fan control	144	85							93
Fan motor replacement, RCA	144					6			37
Lighting, smart power strip							16	22	83
Smart thermostat, lighting					27		14		39
Coil cleaning, smart thermostat, lighting				42	18		7		18
Coil cleaning, smart thermostat, RCA				43	19	7			73
Fan control, coil cleaning, RCA		81		36		6			1,620
Fan control, smart thermostat, lighting		66			13		14		18
Fan motor replacement, coil cleaning, RCA	145			38		6			49
Fan motor replacement, fan control, coil cleaning	131	78		34					1,314
Fan motor replacement, fan control, lighting	122	73					25		27
Smart thermostat, lighting, smart power strip					29		9	22	23
Fan control, coil cleaning, smart thermostat, lighting		76		34	15		5		34
Fan control, coil cleaning, smart thermostat, RCA		84		37	16	6			270
Fan motor replacement, coil cleaning, smart thermostat, RCA	148			39	17	6			19
Fan motor replacement, fan control, coil cleaning, RCA	135	80		35		6			46
Fan motor replacement, fan control, duct testing and sealing, smart thermostat	136	81	120		15				11
Fan motor replacement, fan control, smart thermostat, lighting	127	75			14		24		28
Fan control, coil cleaning, smart thermostat, lighting, smart power strip		81		36	16		10	15	17
Fan control, duct testing and sealing, coil cleaning, smart thermostat, RCA		75	112	33	14	5			74
Fan motor replacement, fan control, coil cleaning, smart thermostat, lighting	118	69		31	13		6		22
Fan motor replacement, fan control, coil cleaning, smart thermostat, RCA	135	80		35	15	6			24

Measure Bundle	Fan motor replacement	Fan controls	Duct testing and sealing	Coil cleaning	Smart thermostat	Refrigerant charge adjustment	Lighting	Smart power strip	Households
Fan motor replacement, fan control, coil cleaning, smart thermostat, lighting, smart power strip	120	72		32	14		9	18	16
Fan motor replacement, fan control, duct testing and sealing, coil cleaning, smart thermostat, RCA	118	70	104	31	13	5			90

Table 6-6 provides gas savings for measures in bundles installed in at least 10 homes in climate zone 12 single family homes.

Table 6-6. Gas savings by bundle for single family participant homes in climate zone 12

Measure Bundle	Duct testing and sealing	Small water measure	Households
Duct testing and sealing, small water measures	32	3	51

Table 6-7 provides gas savings for measures in bundles installed in at least 10 homes in climate zone 10 mobile homes.

Table 6-7. Gas savings by bundle for mobile home participant homes in climate zone 10

Measure Bundle	Duct testing and sealing	Small water measure	Households
Duct testing and sealing	4		152
Duct testing and sealing, small water measures	4	1	123

6.12 Appendix L: Stakeholder comments and evaluator responses

Table 6-8. Stakeholder comments and evaluator responses

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
1	Unknown		Furnace Program Distinction		There is little distinction made among the SDG&E Residential High-Efficiency Furnace Upstream Program, and the SCG Residential High-Efficiency Furnace Upstream Program and SCG Gravity Wall Furnace Programs. The Gravity Wall Furnace Program utilizes a different intervention strategy compared to the other two programs.	All tables in section 4.5 are split by PA. SCG gravity wall furnaces represent the majority (72%) of the 2019 claims, so they dominate the overall result. All of SDGE's claims were from central air furnaces while the vast majority of SCG's claims were from gravity wall furnaces. Thus, the PA split is also representative of the technology split. SDGE had only 1,809 out of 197,494 (<1%) of the 2019 claimed therms (Table 4-21), all central air furnaces. SDGE had a GRR of 45% and an NTGR of 55% for an NRR of 41%. In contrast, almost all of SCG's claims (91% of claims, 72% of savings) were from gravity wall furnaces. We have added a paragraph after table 4-21 providing this additional detail.
2	SCG	4.5	Furnace program design		SoCalGas opposes the notion that there was inadequate program design. The upstream furnace program's goal was to incentivize distributors to stock and sell high-efficiency furnaces. The evaluation states that "the manufacturer indicated only a 20% increase in sales of high efficiency gravity wall furnaces result from the program." SoCalGas believes that the program goal was achieved by the manufacturer stating that sales increased by 20% and opposes the implication that a 20% increase in sales is insignificant.	An increase in sales of gravity wall furnace has no bearing on our finding of "inadequate program design". Our finding of inadequate program design relates to the wall furnace measure programs not collecting sufficient data in terms of location of the installed equipment, customer contact information and all other relevant information so that the newly installed wall furnaces could have been independently verified or the savings substantiated through the approved workplan EM&V activities.

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
3	SCG	4.5	Furnace measures gross results		SoCalGas opposes the evaluated GRR of 0% for gravity wall furnaces. The GRR of 0%, which in turn impacts evaluated gross savings and evaluated net savings, was arrived at due to the inability to conduct an analysis, rather than any kind of analysis concluding there were no savings for gravity wall furnaces. SoCalGas suggests for the overall furnace GRR (and subsequent savings values) calculation, that gravity wall furnaces be removed since there was no analysis conducted on them. To assign a GRR of 0% with no analysis for gravity wall furnaces, then combining it with an analysis-driven GRR for central furnaces is inappropriate and not reflective of true savings.	The evaluation is set-up to estimate savings by measure group. Both the gravity wall furnace and the central furnace are part of the HVAC furnace group. Hence, to correctly evaluate the savings for the HVAC furnace measure group both the measures needs to be included in the analysis. Excluding gravity wall furnace measure from the HVAC furnace measure group savings analysis will be incorrect and provide biased results. The 0% GRR for the gravity wall furnace measure is a result of the program's inability to deliver adequate tracking data that would provide the evaluators the opportunity to identify the benefiting ratepayers and conduct the EM&V analysis as planned.
4	SCG	4.3	Fan Controls gross results		SoCalGas opposes the notion that there are no appreciable savings for fan controls. Footnote 29 reads "for the SCG furnace-focused fan controller measures, the workpaper methodology could not be adapted for simulation modeling and ex ante savings estimates were applied to the analysis process as though they were the modeling output results." There seems to be a lack of rigor in applying the SoCalGas fan control workpaper. We suggest using the reported gross values in assigning savings. Additionally, the report states that the reported NTGR value is retained. The reported NTGR is 90%, not 85%.	As mentioned in footnote 29, the reported ex ante gross savings estimates were referenced in the analysis process as though they were ex post modeling outputs, however the AMI data analysis produced 0 therm savings at the household level for participants with these measures, regardless of the savings estimate feed into the process used for savings disaggregation. For the point about the measure NTGR, the tracked NTGR ratio is 0.85 as it is in the workpaper, but the 5% MEB adder brings the quotient to 90%.
5	SCG	3 (Methodology)	Simulated savings estimates		For savings estimates by measure by climate zone by building type arrived at through simulation, is there a table that reflects the estimated savings for each possible combination of measures, by fuel type?	We have added to the report a breakdown of results by measure combination for high frequency groupings with sufficient sample counts.

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
6	PGE	Overarching	Interactive effects	-	The evaluation found that household-level gross savings fell below the sum of the savings for each individual measure. It would be helpful to understand the extent of interactive effects. Can the evaluators please show or give an example in the report of expected versus actual household-level savings?	The evaluation found household-level gross savings fell below the sum of the savings of installed measures. While interactive effects have an impact on household-level gross savings realization rates, their effect is limited comparably. This suggests that measures installed alone or in combination delivered a lot lower savings than expected. There could be multiple reasons for low household-level savings such as takeback effects and other behavioral changes, repairs of non-working systems, and interactive effects. An analysis of the realization rates of household-level savings from measures installed alone or in combination indicates that in general they differ by 5%, 6%, and 11% for single family, mobile home, and multifamily homes respectively.
7	PGE	Overarching	Interactive effects	-	To inform future program design, can the report please demonstrate which combinations of measures had the greatest degree of interactive effects?	We have added to the report a breakdown of results by measure combination for high frequency groupings with sufficient sample counts.
8	PGE	Overarching	Interactive effects	-	For measures with interactive effects, can the report please show how savings compare when measures are isolated versus combined? How did the evaluation use non-participant comparison groups to isolate measure group effects?	See the added chart on section 4 of the report, Figure 4-1. Overall, household savings realization rates were around 5-10% lower for bundled measures than for stand-alone measures.

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
9	PGE	1.2.2 Duct testing and sealing	Gross savings	9	What are the interactive measures that result in such a low GRR for the duct testing measure? Can the evaluation be more specific on modeling inputs and the assumed bundled measures?	Overall, 95% of the population installed duct sealing along with other measures, while the remaining 5% installed duct sealing alone. Of all the measures installed with duct testing measure, SCT, refrigerant charge adjustment, fan control, and coil cleaning are the most frequent measures installed alongside duct testing and sealing measure. Measure bundles reflect the tracked claims. We have added to the report a breakdown of results by measure combination for high frequency groupings with sufficient sample counts. For modeling inputs, see the updated Table 3-6 in the report.
10	PGE	1.2.2 Duct testing and sealing	Peak demand savings	10	Can the report please provide more detail on why peak demand GRR is much lower than energy consumption GRR? The report states that demand savings were the focus, but the report does not provide much detail on how demand savings were determined and major adjustments made to demand savings (beyond adjustments to energy savings that would also affect demand savings). Additional discussion about this in the report would be very helpful to the reader.	We have added details about the approach used to estimate peak demand reductions. Peak demand savings reflect demand reductions during DEER defined peak periods that are based on specific heat wave definitions. The lower GRRs for peak demand reduction relative to kWh energy GRR is due to non-coincident reduction in demand.
11	PGE	1.2.3 Fan motor controls	Overlap with SCT	11	The evaluators found that fan motor controls were often redundantly installed along with smart communicating thermostats. Can the evaluator please specify in the report how many fan motor controls were installed concurrently with SCTs? How much of the gross savings penalty can be attributed to this factor as opposed to other factors, such as interactive effects?	The overlap between fan controls and smart thermostats is significant: 49% for single family homes, 72% for mobile homes, and 84% multifamily homes. The study design does not allow us to determine with certainty the extent of lost savings due to this versus other factor as this was not a research goal.
12	PGE	3.1 Sample design	Table 3-1 sample targets	22	How were the projects stratified - by energy savings, demand savings, or something else? Could the evaluators add the sampling criteria (e.g., total energy savings in each strata) as another column? This would help illustrate how the strata and targets were identified.	Property manager surveys were post-stratified by PA and savings magnitude. We have added further explanation in section 3.1 of the report.

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
13	PGE	3.2 Data sources	Data sources	23	Can the evaluators please describe in the report the thermostat setpoints assumed since RASS 2019 is not published as of March 2021?	In the simulation model, baseline thermostats setpoints followed an average morning, day, evening, nighttime set-points based on corresponding RASS 2019 survey dataset. The setpoints are arranged by the 4 aforementioned time bins in 16 climate zones. We are not able to publish the RASS 2019 dataset as the RASS report is not yet publicly available.
14	PGE	3.3 Data collection	Gross savings data	24	The report states that sites with net metering or master metering were dropped from the dataset. It's understandable that these sites may make data analysis more challenging, but it also seems that removing these sites from the sample may lead to some bias. What analysis was done, if any, on these sites to ensure that they were not disproportionately representative of specific subsets of the population?	In both cases, we would not be able to estimate savings using whole-home metering data. For master metering, the number of occupied units as well as changes in energy use behavior with occupant turnover prevents us from accurately measuring savings. For net metering, the data we receive includes only net production and consumption information, which means that we do not have visibility into changes in household energy use. The AMI analysis approach enables very large sample sizes and empirically-derived results but does necessitate the exclusion of site with net or master metering.
15	PGE	3.4.2 Impact methodologies	Gross savings analysis	25	The report states: "First-year post periods cover 2018 and 2019 since energy use from this period was unaffected by COVID-19 disruptions. DNV GL extended the analysis of residential HVAC measure savings by examining changes in a second-year post period, which covers 2020. DNV GL's PY2019 evaluation thus involves two different post periods." This approach is difficult to follow. Can the evaluators please clarify this in the report with a graphic, rephrasing, or providing an example? Can the evaluator please provide more detail around why two different post periods were developed and how the PY2020 post period was used?	For the Residential HVAC report, we only conducted analysis and reported findings for only one post period, prior to 2020. We have edited the report to reflect this.

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
16	PGE	3.4.2 Impact methodologies	Gross savings analysis	25	The evaluation extrapolated savings from PY2018 participants to PY2019 participants. What variables were used to extrapolate those savings? Was it purely based on climate zone and building type, or were other factors such as square footage and occupancy taken into account? Can the evaluator please discuss the limitations of this approach?	We used data from PY2018 to determine measure savings per unit in each climate zone and housing type. We multiplied the per unit savings by the number of participants in each climate zone and housing type in PY2019. This approach assumes that the unit savings for the same measures in the same location and housing type are similar in both years. For example, we assume that the savings from duct sealing in a particular climate zone and housing type will be the same from year to year, after controlling for weather effects. These are reasonable assumptions to make if the technologies installed do not change dramatically from PY2018 to PY2019. Since these are population-wide studies, the characteristics of participants in each year are assumed to be the same.
17	PGE	3.4.3 Comparison groups	Comparison group selection	27	Can the evaluator please provide more detail in the report on how comparison groups were determined? For example, were these homes similar in terms of size, location, and/or demographics (e.g., income)? Also, can the evaluator explain how comparison groups were used to isolate measure group effects?	We have added details about the comparison group matching approach. We constructed matched comparison groups from general population customers, stratified by dwelling type and geography. We matched using annual energy use, the ratio of summer-to-winter energy use to account for seasonality, tenure, and for electricity, 6 p.m. kWh for identified 'heat wave' periods used to capture peak demand conditions. 'Heat wave' periods were identified for each climate zone as weekdays between June through September where most customers had their maximum 6 p.m. kWh. We did not have sufficient information regarding other household characteristics such as size or income for the general population.
18	PGE	3.4.4 eQUEST modeling	Non-evaluated measures	29	The report states that non-evaluated measures were subtracted from household savings before apportioning the balance among the evaluated savings. Can the evaluator please provide more detail about this in the report? What were the non-evaluated measures? What share of	We have clarified the measure disaggregation approach in the report. This is the text we have added, "We apportioned the estimated whole-home savings to measure savings in proportion to the engineering savings estimates for evaluated measures or tracking savings estimates for non-evaluated measures (lighting,

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
					household-level savings came from non-evaluated measures? How were interactive effects between evaluated and non-evaluated measures accounted for?	smart power strips, DHW)." As the non-evaluated measures were lighting, smart power strips, and DHW, we did not anticipate large interactive effects because they are not weather correlated.
19	PGE	4.1.1 Gross impact findings	Coil cleaning GRRs	33	The evaluators found very different GRRs between the utilities for coil cleaning. Can they explain why in the report?	The underlying models used to estimate savings are the same for all PAs. The differences are likely due to the climate zones and housing types in which the coil cleaning was performed as well as the different measure mixes delivered and the relative savings claimed.
20	PGE	4.3.1 Gross impact findings	Fan controls gross savings	38	The report states: "The low electricity savings result from the competing effects of this measure and smart communicating thermostats, both of which are capable of delaying fan turn-off and were often reported to be installed together". Can the evaluators state in the report how often this occurred? Also, while smart thermostats have this capability, did the evaluators confirm those thermostats had that feature and it was enabled? Or did they somehow verify this feature was enabled through the AMI analysis?	In the program year 2019, 58% of fan controls were installed with a smart communicating thermostat. While we do know that smart thermostats have the capability to delay fan turn-off, it was not within the scope of this evaluation to confirm whether the feature was enabled. The analysis supports the idea that there is redundancy in the way the two measures functioned, which appears to have affected savings.
21	PGE	6.4.3 Decomposition of whole-home savings	eQuest Model	79	The simulation approach lacks detail related to the specific efficiency measures. For examples, how is each measure modeled in eQUEST, and what are the inputs to the energy models? Since many measures are not straightforward to model, can the evaluator please provide in the report key modeling inputs for the baseline and proposed measure?	We have added the modeling input parameters to Table 3-6 in the report. A high-level description of the simulation input parameters is presented below: **fan motor replacement**: supply-kW/flow update (0.00065 to 0.0004 kW/cfm), supply-delta-T update (2.054 to 1.012 F). **fan controls (Cooling)**: Cooling EIR adjustment (efficient EIR = 0.87025 x baseline EIR) **duct sealing**: duct air loss % reduction (30.416% to 15% for SFM/MFM, 33.52% to 15% for DMO)

Comment #	Entity	Section	Topic	Page	QUESTION or COMMENT	Evaluator Response
						coil cleaning: Cooling EIR adjustment (baseline EIR = efficient EIR x 1.065) and Coil bypass factor adjustment (baseline Coil BF = efficient coil BF x 0.99574) **refrigerant charge adjustment**: Cooling EIR adjustment (baseline EIR = efficient EIR x 1.0106976) **smart thermostat**: see above (comment #8) on description on how thermostat setpoints are modelled **efficient furnace**: furnace Heating-HIR adjustment (equivalent baseline AFUE: 78, 80, 83; equivalent efficient AFUE: 93.5, 95.5, 96.5, 97.5)
22	PGE	6.4.3 Decomposition of whole-home savings	eQuest Model	79	The evaluator only describes in words the process to disaggregate savings. Can the evaluator also provide actual simulation results for combined measures, incremental savings for each measure, and how measure savings compared when it is combined vs not combined? The word "massaged" is used in the report to describe the disaggregation process. Can the evaluators please provide more details in the report about how savings were disaggregated?	We have added a breakdown of results by measure combination for high frequency groupings with sufficient sample counts. Additionally, we have added chart (Figure 4-1) in section 4 of the report presenting the differences in realization rates for measures installed alone compared with measures installed in bundles. Overall, household savings realization rates were around 5-10% lower for bundled measures than for stand-alone measures. We have clarified the measure disaggregation approach in the report by adding the following text, "We apportioned the estimated whole-home savings to measure savings in proportion to the engineering savings estimates for evaluated measures or tracking savings estimates for non-evaluated measures (lighting, smart power strips, DHW)." The non-evaluated measures were lighting, smart power strips, and DHW, which are not expected to have significant interactive effects with HVAC measures because they are not weather sensitive.