FINAL IMPACT EVALUATION REPORT

Southern California Edison's Plug Load and Appliance Program, Program Year 2021

California Public Utilities Commission

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1 EXECUTIVE SUMMARY

DNV evaluated Southern California Edison's (SCE's) Plug Load and Appliance (PLA) program for program year (PY) 2021 as part of the California Public Utilities Commission (CPUC) Energy Division (ED) Evaluation, Measurement & Verification contract. This program was selected for evaluation due to its high prevalence of claimed water heating and space heating fuel substitution energy saving technologies, also referred to as measures, for residential customers. These space heating and water heating fuel substitution measures use electrically fuelled heat pump technologies in place of traditional gas-fuelled domestic water heaters (DHW) or furnaces that are part of the homes' heating, ventilation, and air conditioning (HVAC) systems to efficiently electrify these end-uses to support California's decarbonization goals.[1] These technologies contribute to over 56% of the reported program attributable (net) lifecycle electric energy (kWh) savings [2] from prescriptive energy efficiency claims for PY2021. [3]

We collected and analyzed available customer utility meter data to assess the annual energy impacts from the program's claimed measures. Where available, we compared the program participants' change in annual gas and electrical energy consumption before and after the fuel substitution retrofit against non-program participants over the same period. This year we expanded our analysis to include the distribution of impacts realized by the participants in the study and segmented the impacts according to circumstances preceding the retrofit. We also sought to further characterize the participants to identify the portion of hard-to-reach (HTR)[4] customers served by the program. For the space conditioning measures, we conducted end-user surveys of HVAC equipment to better understand participant characteristics and the circumstances of their retrofits. We also attempted to survey the DHW equipment distributors, but not enough participated in the survey, citing a lack of program awareness.

The evaluation of the SCE PLA program in PY2021 includes the following findings:

- The HVAC fuel substitution measures were found to save less site-level gross gas energy than expected, with central HVAC measures achieving around half (54%) of expected gas savings, down from 75% in PY2020, and ductless HVAC measures saving far less gas site-level gross[5] gas energy savings at 6% of expectation, which is similar to the PY2020 finding. The gross site-level electric energy increases remain below expectation but increased relative to PY2020 findings with central HVAC measures realizing 69% of the expected increase, up from 64%, and the ductless HVAC measure realizing 85% of the expected electric energy increase, up from 68%.
- HVAC fuel substitution measures source energy and C02 emissions savings are proportionally impacted by the lower site-level gas savings and electric energy increases, and thus also fall short of expectations for these claimed measures.
- The HVAC fuel substitution measures bill impact analysis produced modest average cost savings for the participants with HVAC measures. The magnitude of the gas bill savings and electric bill increases were generally smaller for participants enrolled in California Alternate Rates for Energy (CARE) or Family Electric Rate Assistance Program (FERA) relative to all participants due to lower baseline consumption. However, average cost savings were similar for both groups.
- Participants across all HVAC measures were likely to own their homes, have attained a college degree or higher, and have household incomes greater than $50,000. Ductless heat pump participants were enrolled in CARE/FERA more than central heat pump and heat pump replacement participants.

1 DNV, CPUC Group A 2021 Workplan, August 2022, https://pda.energydataweb.com/#!/documents/2659/view

2 Lifecycle energy savings is the total energy savings accrued over the expected service life of the technology

3 DNV, CPUC Group A 2021 Workplan, August 2022, https://pda.energydataweb.com/#!/documents/2659/view

4 The criteria for residential HTR customers is the combination of a geographic prerequisite plus at least one of the following criteria: primary language, income, or housing type. Commercial HTR customers are defined by a combination of a geographic requirement plus at least one of the following criteria: primary language, business size, or leased or rented facility. Specific details can be found here: Statewide Deemed Workpaper Rulebook.

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

- Participants across all HVAC measures were the most satisfied with their contractors and equipment and the least satisfied with their savings.

1.1 Study background and objectives

SCE's PLA program is a traditional, multi-faceted energy saving program that varies in design depending on market segment, measures, and technology. The program was designed to engage and support DHW manufacturers or HVAC equipment distributors and the contractor purchasing their products with the claimed measures implemented through either an upstream or midstream program design:

- The upstream component incentivizes manufacturers to reduce the cost of the water heating heat pump technology to their customers, who are the equipment distributors. The manufacturers interface with downstream market actors and supply the program with information to support the savings claims. Heat pump water heater fuel substitution is the primary measure for this component.
- The midstream component incentivizes and supports distributors to promote residential heat pump technology. Via these participating distributors, it also provides marketing support for contractors and downstream monetary incentives to utility customer end-users. Measures for this component include ductless and central HVAC fuel substitution and residential HVAC heat pump replacement.

Table 1-1 presents measure groups that make up the program's PY2021 reported savings. The ductless and HVAC fuel substitution measures make up over 98% of the claimed savings for this program.

Table 1-1. PY2021 Plug Load and Appliance Program reported savings

Measure	No. of claims	First year kW		First year kWh		Lifecycle kWh	First year therm		Lifecycle therm
		Gross	Net	Gross	Net	Net	Gross	Net	Net
Ductless HVAC - fuel substitution	7913	0	0	-2,406,485	-2,406,399	-36,095,981	1,310,954	1,310,910	19,663,657
Central HVAC - fuel substitution	1036	0	0	-974,286	-974,286	-14,614,287	179,287	179,287	2,689,299
Heat pump water heater - fuel substitution	125	0	0	-174,840	-174,840	-1,748,400	23,283	23,283	232,830
Residential HVAC heat pump replacement	184	74	45	119,399	71,639	1,074,591	0	0	0
Total	**9258**	**74**	**45**	**-3,436,212**	**-3,483,885**	**-51,384,077**	**1,513,523**	**1,513,480**	**22,585,786**

For PY2021, we focused on evaluating site energy savings, source energy and emission savings for fuel substitution measures, as well as the type of customer this program reaches and why. Our evaluation of HVAC fuel substitution measures in PY2020 informed us about the effects of bill impacts on the average participant. We learned that the distribution of bill impacts may cause low-income customers to pay higher energy bills. Therefore, in addition to energy savings, our evaluation for PY2021 considers how the program impacts HTR customers. It should be noted the program did not continue into PY2022.

1.2 Study approach

As in prior evaluations, we estimated gross and net savings and studied the distribution of savings and bill impacts on participants. In support of recent CPUC decisions, for PY2021 we also determined the evaluated program cost-effectiveness (CE) and Total System Benefit (TSB). For this year we also looked at the effectiveness of the program's design in addition to its success on the measure level. Table 1-2 provides an overview of our study approach for PY2021.

Table 1-2. SCE PLA PY2021 evaluation approach

Evaluation approach	Method(s)	Reason(s) for inclusion
Gross and net savings	Analysis of utility meter data changes Attribution surveys and applying estimated attribution values (NTGRs) to achieve net savings for heat pump water heating measures	This program has the largest gas-to-electric conversion fuel substitution savings claims in the residential sector
Distribution of savings and bill impacts	Energy bill assessment from site energy savings	To better understand the distribution of savings and bill impacts among participants, particularly HTR participants
Cost-effectiveness and Total System Benefit	Cost Effectiveness Tool (CET)	Starting in 2022, PAs are required to report TSB along with kWh, kW, and therms savings. By 2024, TSB will become the singular metric for evaluating energy efficiency programs
Participant characterization and benchmarking	Customer surveys, program administrator (PA) interviews, and program information	To better understand participant characteristics such as what kinds of customers the programs are reaching

1.3 Key findings

1.3.1 Site energy savings

Table 1-3 below provides a summary of the program's success in providing gas and electric savings at the utility customer's site through the two technologies. The table presents evaluated net savings compared with the PA-reported net savings, and then in the last column, the net realization rate (NRR). The NRR removes the savings from installations that would have happened even if there were no incentives 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. In general, the higher the NRR value, the greater the program's achieved savings. However, because there are gas-to-electric fuel substitution measures, the electric impacts for these measures are not energy savings but energy consumption increases. Therefore, for fuel substitution a lower electric NRR and a higher gas NRR are desirable, and the ratio of gas energy savings to electric energy increases is important for the measure passing the fuel substitution test components.

Table 1-3. Net electric and gas energy savings results by technology

Technology (Measure) group	Reported net savings	Evaluated net savings	Net Realization Rate (NRR)
Electric Energy (kWh)			
Ductless HVAC – fuel substitution	-2,406,399	-817,643	34%
Central HVAC – fuel substitution	-974,286	-380,965	39%
Residential HVAC heat pump replacement	71,639	-74,783	-104%
Heat pump water heater – fuel substitution*	-174,840	-174,840	100%
Total	**-3,483,885**	**-1,448,230**	**42%**
Gas Energy (Therms)			
Ductless HVAC – fuel substitution	1,310,910	30,816	2%
Central HVAC – fuel substitution	179,287	55,121	31%
Residential HVAC heat pump replacement**	-	12,332	-
Heat pump water heater – fuel substitution*	23,283	23,283	100%
Total	**1,513,480**	**121,551**	**8%**

*Due to the very limited information available from which to draw any conclusive independent findings regarding the presence or impacts of these Heat Pump Water Heater – fuel substitution measures, we were unable to produce evaluated savings or program attribution estimates and are passing through the claimed savings values. While it appears the program followed the minimum data collection requirements for the program design (upstream), this left significant gaps in the evaluability of this technology group. Therefore, there remains considerable uncertainty about the validity and accuracy of the reported impacts and benefits of this technology.
**The Residential HVAC heat pump replacement technology group is not fuel substitution and represents electric only impacts and therefore did not report gas savings.

1.3.1.1 Ductless HVAC fuel substitution technology group

The ductless HVAC heat pump fuel substitution technology is intended to replace the use of an existing residential ductless natural gas furnace such as a gravity wall furnace, either with or without a separate existing residential ductless window air conditioner unit. Thus, the heat pump provides high-efficiency electric heating and cooling as a substitute for a gas heating system and in many cases a standard efficiency cooling system as well. In general, relative to central ducted systems, ductless systems are more compact and have lower heating and cooling capacities, so they are usually installed in smaller residential dwelling units.

Table 1-4 presents the PY2021 statewide reported and evaluated savings summary for the ductless residential HVAC fuel substitution technology group. The evaluated gross gas (therm) savings is only 6% of the reported savings, while the evaluated gross electric (kWh) increase is 85% of the PA-reported value. Evaluation results indicate that the ductless HVAC fuel substitution is not meeting expectations to significantly offset pre-retrofit gas heating, yet it is adding year-round electric energy consumption. This is somewhat likely because, as survey respondents indicate, the ductless heat pump measure is not often replacing an existing gas heating system, but the analysis also shows this doesn't account for all the unachieved gas savings. Combining the consumption analysis and the survey results indicates that on average, when the ductless HVAC system does replace an existing heating system, the gas savings are 19% of what was reported for those claims.

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Table 1-4. Ductless HVAC fuel substitution first-year savings

Reported gross savings	GRR	Evaluated gross savings	Reported NTGR	Evaluated NTGR	Reported net savings	Evaluated net savings	NRR
			Electric energy (kWh)				
-2,406,485	85%	-2,044,107	100%	40%	-2,406,399	-817,643	34%
			Gas energy (Therms)				
1,310,954	6%	77,040	100%	40%	1,310,910	30,816	2%

1.3.1.2 Central HVAC fuel substitution technology group

The central HVAC heat pump fuel substitution technology is intended to replace the use of an existing residential central ducted natural gas furnace and air conditioning HVAC system. Like the ductless technology, the central heat pump provides high efficiency electric heating and cooling as a substitute to existing central gas furnace and AC systems.

Table 1-5 presents the PY2021 statewide reported and evaluated savings summary for the central residential HVAC fuel substitution technology group. The evaluated gross gas (therm) savings is 54% of the value reported savings, while the evaluated gross electric (kWh) increase is 69% of the value the PA reported. The evaluation results indicate that the central HVAC fuel substitution is serving to offset a slight majority of pre-retrofit gas heating while also exhibiting a cooling efficiency improvement over the pre-retrofit condition. Almost all survey responses (99%) indicate that these central heat pump systems replaced an existing heating system, while a majority (73%) indicate the heat pump replaced a central furnace, and a minority (19%) indicate it replaced an existing central heat pump.

Table 1-5. Central HVAC fuel substitution first-year savings

Reported gross savings	GRR	Evaluated gross savings	Reported NTGR	Evaluated NTGR	Reported net savings	Evaluated net savings	NRR
			Electric energy (kWh)				
-974,286	69%	-668,359	100%	57%	-974,286	-380,965	39%
			Gas energy (therms)				
179,287	54%	96,703	100%	57%	179,287	55,121	31%

1.3.1.3 Residential HVAC heat pump replacement technology group

The residential HVAC heat pump replacement technology is intended to replace the use of an existing residential central (ducted) electric heating and air conditioning HVAC system. Like the central HVAC fuel substitution technology, the replacement heat pump provides high efficiency electric heating and cooling but as a replacement to existing and minimum code compliant central electric heat pump systems instead of an existing gas-fired heating system as is the case with the fuel substitution measure.

Table 1-6 presents the PY2021 statewide reported and evaluated savings summary for the residential HVAC heat pump replacement technology group. The program reported the gross electric (kWh) savings indicating this technology group represents an electric heat pump replacement. The evaluated gross electric (kWh) savings is -104% of the value of reported savings. The evaluation results indicate that the residential HVAC heat pump replacement is leading to an increase in electric usage over the pre-retrofit condition. Although the program did not report any gas savings due to these seemingly electric energy efficiency measures, the evaluated gross therm savings is moderate, indicating this technology group may comprise heat pumps replacing natural gas equipment. It's likely that some of the claims within the category contain fuel substitution, leading to an increase in electric usage and a decrease in gas usage, even though it wasn't reported as such. If these installations do represent fuel substitution, the appropriate evaluated NTGR would be 57%.

Table 1-6. Residential HVAC heat pump replacement first-year savings

Reported gross savings	GRR	Evaluated gross savings	Reported NTGR	Evaluated NTGR	Reported net savings	Evaluated net savings	NRR
Electric energy (kWh)							
119,399	-104%	-124,638	60%	60%	71,639	-74,783	-104%
Gas energy (Therms)							
0	**-**	20,553	0	60%	0	12,332	-

1.3.2 Bill impacts

We evaluated the cost impacts[6] of the HVAC measures on participants' utility bills by combining the consumption data analysis results with rate schedule information from SCE and Southern California Gas Company (SCG). We used SCG's residential general service rates for gas and SCE's residential service rates for electric that apply to each participating customer to illustrate the cost impact of gas use reduction and electric use increase from the HVAC measures. We assumed the same rates are applicable before and after retrofit to provide a practical comparison of pre-and post-installation results. We did not include fixed costs in this analysis, as most participants continued to have some gas service following the heat pump installations.

The results of the bill impact assessment are presented in Table 1-7. Central HVAC systems that replaced less efficient gas heating systems afforded utility customers an average annual bill savings of $89. Ductless HVAC systems led to an average annual bill savings of $31 for participating utility customers. Average annual bill savings for ductless HVAC systems were driven by smaller increases in electric cooling load and greater savings in gas consumption relative to PY2020. The gas bill savings associated with each technology outweighed cost increases from their increased electric load. Overall, the program resulted in an average annual bill savings of $46 per participant and total bill savings of $307,505 across all participants.

Table 1-7. SCE PLA PY2021 bill impacts assessment

Technology	Average annual bill impact			Total participants	Total bill impact
	Electric	Gas	Total		
Ductless HVAC	$55	-$86	-$31	5,533	-$169,816
Central HVAC	$141	-$230	-$89	905	-$80,493
Residential HVAC heat pump replacement	$55	-$165	-$110	338	-$37,276
Overall	**$67**	**-$113**	**-$46**	**6,711**	**-$307,505**

Bill savings are indicated by a negative value and cost increases are indicated by a positive value.

The results of the bill impact assessment for participating customers enrolled in CARE or FERA are presented in Table 1-8. The gas bill savings associated with each technology outweighed cost increases from their increased electric load for these utility customers. While the magnitude of the gas bill savings and electric bill increases tend to be smaller for these utility customers relative to all participating customers, the average annual total bill savings are similar. Since customers enrolled in CARE or FERA have lower baseline consumption, gas consumption savings and electric load increases tend to be less. Overall, the program resulted in average annual bill savings of $41 and total bill savings of $72,238 for participating customers enrolled in CARE or FERA.

6 This does not factor in the cost of installation or equipment upgrades. This is strictly the bill impact from energy consumption changes.

Table 1-8. SCE PLA PY2021 CARE/FERA bill impacts assessment

Technology	Average annual bill impact			Total participants	Total bill impact
	Electric	Gas	Total		
Ductless HVAC	$30	-$68	-$37	1,344	-$57,391
Central HVAC	$107	-$159	-$53	119	-$7,743
Residential HVAC heat pump replacement	$65	-$121	-$56	89	-$6,615
Overall	**$38**	**-$79**	**-$41**	**1,524**	**-$72,238**

Bill savings are indicated by a negative value and cost increases are indicated by a positive value.

1.3.3 Participant characterization

HVAC measure participants were asked about household characteristics. The results are presented below in Table 1-9. Most participants across all HVAC types own their homes, with only ductless heat pump participants reporting they rent their homes (1%). All participants were likely to have attained an educational level of college or higher, with central heat pump participants reporting this level of education more so than the ductless heat pump and heat pump replacement participants. All participants reported a median income between $50,000 - $150,000. However, ductless participants were more likely than the other measure groups to report incomes both above and below that range. Additionally, ductless participants were more likely to report they were enrolled in a discounted utility rate than the other measure groups. This would suggest the ductless heat pump measures might be reaching a more economically diverse group than the other two.

Table 1-9. SCE PLA PY2021 Participant characterization survey results

Characteristics	PY 2021 Central heat pump participants (n=117)	PY 2021 Ductless heat pump participants (n=380)	PY 2021 Heat pump participants (n=39)
	Income		
Less than $50,000	14%	19%	13%
More than $50,000 and less than $150,000	47%	36%	54%
More than $150,000	40%	44%	33%
	Education		
College or higher	81%	71%	69%
High school or less	13%	13%	17%
Own	100%	99%	100%
Rent	0%	1%	0%
	CARE/FERA		
Enrolled in discounted utility rate (CARE or FERA)	6%	10%	5%

1.3.4 Participant experience

Participants were asked about their experience with various aspects of their participation in the program. The results are presented below in Table 1-10. Participants across all HVAC measures were the most satisfied with their contractors and equipment, with heat pump replacement participants showing the highest satisfaction overall. Participants were the least satisfied with savings, with central heat pump participants showing the lowest satisfaction (58%). Despite the lower satisfaction with savings, only a quarter (20-28%) of participants across all HVAC measures reported noticing their energy costs increase.

Table 1-10. SCE PLA PY2021 Participant satisfaction survey results

Characteristics	PY 2021 Central heat pump participants (n=117)	PY 2021 Ductless heat pump participants (n=380)	PY 2021 Heat pump participants (n=39)
	Satisfaction		
Satisfaction overall	79%	76%	82%
Satisfaction with contractor	79%	77%	85%
Satisfaction with equipment	79%	79%	85%
Satisfaction with savings	58%	62%	64%

1.4 Recommendations and conclusions

Table 1-11 below presents a summary of our key findings and recommendations.

Table 1-11. SCE PLA Key findings and recommendations summary

Measure type & focus	Key finding(s)	Recommendation(s)
HVAC measure program data	• The breadth of the HVAC measure documentation data was sufficient, but the quality could be improved.	• SCE and their implementers ought to increase efforts to train participating midstream program distributors on consistent and accurate data recording. • SCE and their implementers ought to conduct regular quality control reviews of the data prior to submittal. • SCE and their implementers ought to design program documentation to include SCE's premise and customer identifier fields. • More documentation and linking program data to utility customer database information to help benefit the certainty of evaluated savings.
Ductless HVAC fuel substitution measure impacts	• These systems fell short of expectations for gas savings. This is somewhat because, as survey respondents indicate, the ductless heat pump measure is not often replacing an existing gas heating system, but the analysis also shows this doesn't account for all the unachieved gas savings. Combining the consumption analysis and the survey results indicates	• A best practice for SCE would be to implement controls and other program design aspects to ensure normal replacement claims are offsetting existing gas heating. • The gross savings for the ductless HVAC technology should be reviewed considering the poor achieved gas savings from consecutive (PY2020 and PY2021) impact evaluations.

Measure type & focus	Key finding(s)	Recommendation(s)
	that on average, when the ductless HVAC system does replace an existing heating system, the gas savings are 19% of what was reported for those claims.	
Low heat pump water heater fuel substitution measure evaluability	• The claimed DHW measure installations were not verifiable and their gross impacts (site energy, source energy, and emissions) remain untested and uncertain due to the extremely limited available data collected by the program's upstream delivery type.	• SCE ought to consider a midstream program design, similar to the ductless HVAC fuel substitution program. This will help reliably collect higher quality equipment details, market actors' contact information, and increase efforts to ensure heat pump water heater claims are installed within the service territory.

2 INTRODUCTION

This report presents DNV's energy savings estimates (impact evaluation) of residential heating, ventilation, and air conditioning (HVAC) heat pump fuel substitution technology groups (measures) that are part of the California Public Utilities Commission (CPUC) HVAC Research Roadmap. The primary results of this evaluation are the estimated site energy savings (in kWh and therms), source energy savings (in MMBtu), and greenhouse gas (GHG) emissions reduction (in metric tons of carbon dioxide or CO2) achieved by two selected HVAC measures—residential ductless HVAC heat pump fuel substitution and residential central HVAC heat pump fuel substitution—in program year (PY) 2021.

2.1 Program description

Starting with PY2020, the primary focus of Southern California Edison's (SCE's) Plug Load and Appliance (PLA) program has been to promote residential heat pumps for HVAC and water heating within its electric service territory, especially fuel substitution gas-to-electric decarbonization measures, ahead of the program administrator's (PA's) transition to statewide third-party HVAC and water heating programs. SCE's PLA program is a traditional, multi-faceted energy saving program that varies in design depending on market segment, measures, and technology. The program was designed to engage and support domestic hot water heaters (DHW) manufacturers or HVAC equipment distributors and the contractor purchasing their products with the claimed measures implemented through either an upstream or midstream program design. The upstream design incentivizes manufacturers to reduce the cost of the water heating heat pump technology to their customers, who are the equipment distributors. The manufacturers interface with downstream market actors and supply the program with information to support the savings claims. The midstream design incentivizes and supports distributors to promote residential heat pump technology. Via these participating distributors, the program also provides marketing support for contractors and downstream monetary incentives to utility customer end users. Measures within the midstream design include ductless and central HVAC fuel substitution and residential HVAC heat pump replacement.

2.2 Research objectives

The goals of the study were to estimate energy, environmental, and utility customer cost impact results from the program and to provide recommendations to stakeholders based on these findings. The specific research objectives of the evaluation include the following:

- Estimate the site energy savings for the program and its claimed measures.
- Determine reasons for differences between evaluated (ex post) and reported (ex ante) site energy savings, and as necessary, assess how to improve the ratio of evaluated savings to reported savings (realization rates). Identify issues with respect to reported impact methods, inputs, and procedures, and make recommendations to improve savings estimates and realization rates of the evaluated measure groups.
- Determine the prevalence of different existing condition baselines (equipment, fuel, and use) for this fuel substitution measure.
- Provide results and data that will assist with updating reported measure packages and the California Database for Energy Efficiency Resources (DEER) values.
- Determine the source energy and emissions reductions from the fuel substitution measures claimed by the program.
- Determine the distribution of savings and bill impacts and the percentage of participants that may be paying high bills.
- Determine the cost effectiveness and Total System Benefit (TSB) of the reported and evaluated savings using the cost effectiveness tool (CET) on the California Energy Data and Reporting System (CEDARs).
- Determine what portion of program participants qualify as hard-to-reach (HTR) customers.
- Determine the influences of utility customers' decisions to adopt fuel substitution and higher-tier equipment.

- Understand the effectiveness of program design and measure delivery in achieving energy consumption and emissions savings across claimed measures.

3 METHODOLOGY

This section provides high level descriptions of the data collection activities of the evaluation including the identification of participants and primary research data collection efforts, the methods used to evaluate site energy savings, CO_2 GHG emissions reductions, and bill impacts. Table 3-1 provides a summary of DNV's research activities to evaluate the impact of HVAC heat pumps.

Table 3-1. Impact evaluation activities

Task	Research activity
Identification of program participant data	Map end user addresses to utility addresses to identify customer account IDs (premise and customer account numbers). Customer account IDs were used to request consumption data.
Primary research data collection	Survey the end users for inputs to support impact calculations and household characteristics.
Calculate ex post site savings estimates	Calculate the normalized annual consumption and changes in annual gas and electric use of sites that installed HVAC heat pumps through SCE's PY2021 incentive program.
Calculate source energy and CO_2 emissions impacts	Calculate the amount of lifecycle source energy savings resulting from the HVAC heat pumps through SCE's PY2021 incentive program. Calculate the lifecycle CO_2 GHG savings resulting from the HVAC heat pumps through SCE's PY2021 incentive program.
Calculate bill impacts	Calculate the electric and gas bill impacts of energy use changes associated with installed heat pumps.

3.1 Data collection

In this section, DNV provides the data sources, collection, and sampling approach used in support of primary research effects.

3.1.1 Data sources

Table 3-2 provides the list of data, their sources, and their role in the analysis DNV conducted to understand participation and program performance.[7]

Table 3-2. Data sources and role in analysis

Data type and source	Role in analysis
Program tracking data	DNV sourced information about program participation at the claim level from tracking data that SCE filed with the CPUC in CEDARS. DNV analyzed and cleaned the dataset. In addition to tracking data, obtained end use customer participant lists from the utility. The tracking data and end use customer participant lists were used to

7 CPUC, "Group A Evaluation, Measurement & Verification of Program Year 2021 Workplan," August 2022, https://pda.energydataweb.com/#!/documents/2659/view

Data type and source	Role in analysis
	identify program participants, installed measures, and ex ante savings.
Utility billing and Advanced Metering Infrastructure (AMI) data	DNV obtained energy consumption data at the customer account level from SCE to model energy consumption and estimate program savings. DNV used the data to analyze energy savings relative to annual energy consumption and to obtain rates to identify those who are on the California Alternate Rates for Energy (CARE) program or the Family Electric Rate Assistance (FERA) program, and green tariff/rates to aid in participation characterization.
Customer Information system (CIS) data	DNV obtained supplementary information (location, climate zones, and rates) on participants from utility customer information tables to understand participation patterns.
Program information	DNV also requested additional participant information (account numbers, contact names, emails, and phone numbers), information on replaced and installed measures, and program information (budget spending, marketing, and outreach) for the evaluation to understand participation patterns and assess program performance.
U.S. Census data	DNV supplemented participant information (such as income, location, language, and rental status) from U.S. Census data at the block group level and mapped this information to program areas to understand participation characteristics and program performance.
CalEnviro Screen	The California Environmental Protection Agency (CalEPA) calculates this metric, which provides a granular geographic picture of the environmental, public health, and socioeconomic conditions in California's 8,000 census tracts. It enables a relative ranking of the pollution burdens and socioeconomic vulnerabilities of communities across CA. DNV used it to define DACs for program performance assessment and an appraisal of DAC participation in PLA.
Web and telephone surveys	DNV performed web surveys with customers to collect information on customer characteristics, the condition of installed measures, and the perception of program benefits and barriers. DNV used the data collected to

Data type and source	Role in analysis
	assess program performance, characterize participants, and gain insight into customers' experiences. Telephone surveys were conducted with equipment distributors in an effort to assess the heat pump water heater program performance.
In-depth interviews	DNV conducted in-depth interviews with SCE staff, program implementers, and, where possible, participating distributors to understand program delivery. Then DNV collected information on measure selection, the effect of program rules on participation, the promotion of other programs, and program information tracking for program performance assessment.

3.1.2 Sampling

DNV used an attempted census as the sampling approach for all interviews and surveys, meaning the company attempted to survey the population of participating end users instead of a sample or subset of the population. DNV issued a survey request via email to the entire population of participating end user utility customers who installed HVAC heat pumps in PY2021 with a goal of a 10% or greater completed response rate to inform program attribution, understand baseline conditions, energy use behavior changes, and participant program experience. Table 3-3 provides the size of the population and sample of participating end user customers by technology group. The evaluation also collected program-related information from SCE program staff.

Table 3-3. Residential HVAC heat pump utility customer sample

Technology group	Value	Utility customers
Central HVAC fuel substitution	N	890
	n	117
Ductless HVAC fuel substitution	N	5,007
	n	380
Residential HVAC heat pump replacement	N	323
	n	39

DNV conducted the gross savings analysis as a census to include the largest percentage of the program population as possible given the expected attrition from account matching and AMI data completeness.

3.1.3 Participant account identification

SCE's program offered fuel substitution heat pump measures through distributors that worked with contractors to install them at participating utility customer sites. Although the program did not collect utility customer identifiers, which are required to measure changes in energy use from the installation of the measures, it did collect installation street addresses and utility customer names and email addresses. DNV mapped the installation street addresses and utility customers' names and email addresses to utility customer information records to identify customer account and premise numbers.

Table 3-4 provides the steps DNV took to identify participant customer account IDs (including premise numbers that identify the location of participating sites and customer numbers that identify the households that participated) along with the number of participants identified. The process involved matching installation addresses provided by SCE with utility addresses that are linked to SCE electric and SCG gas premise numbers. While address matching provided the premise numbers of participating sites, participating utility customer names were matched with customer names in SCE and SCG utility records to identify their associated electric and gas customer numbers. DNV requested AMI data for all participating households with identified customer and premise numbers.

Table 3-4. Residential HVAC heat pump participant identification steps

Identification steps	SCE				SCG			
	Central HP	Ductless HP	Heat pump	Total	Central HP	Ductless HP	Heat pump	Total
Total participating household addresses with heat pump installations	905	5,533	338	6,711	-	-	-	-
Total participating households with identified customer and premise numbers in utility customer information files by IOU	809	4,526	255	5,520	658	3,618	234	4,445

3.1.4 Customer data cleaning attrition

Site-level energy impact models included data from participating electric and gas customers. The data for these participants were based on customer and premise IDs identified through DNV's address matching efforts, described in the prior section. The address matching effort resulted in the identification of approximately 5,500 electric and 4,400 gas customers from whom DNV collected and cleaned energy data. Of these, approximately 3,300 electric and 2,900 gas customers had sufficient data available for the analysis.

Table 3-5 provides participants' data identified for inclusion in the study, data attrition, and final customer counts used in the analysis.

Table 3-5. Participant counts used in HVAC heat pump evaluation

Participant data attrition	Electric	Gas
Customers' addresses with heat pump claims in 2021*	6,711	
Customers with mapped account IDs	5,520	4,445
Customers for whom some data was received	5,487	4,431
Customers with matched and sufficient data used in the analysis**	**3,262**	**2,879**
Customers with ductless HVAC fuel substitution included in the analysis***	2,691	2,277
Customers with central HVAC fuel substitution included in the analysis***	453	464
Customers with heat pump replacements included in the analysis***	118	138

*Claimed by SCE's rebate program – SCE electric and SCG gas customer IDs identified through address matching
**Customers without solar and at least 90% of pre- and post-installation period data
***Customers with matched and sufficient data used in the analysis

3.2 Evaluation approach

In this section, DNV provides the evaluation's savings results of residential HVAC heat pump technologies, reporting on site energy, source energy and CO_2 emissions savings, and typical annual energy bill impacts.

3.2.1 Site energy savings

Site energy savings are those realized at the utility customer site and reported by SCE as savings. DNV estimated site-level gross energy savings and the portion of these savings that are attributable to the programs that delivered the measures' net energy savings. This section provides the methods DNV used to estimate both gross and net savings for the PY2021 SCE Plug Load and Appliance program impact evaluation.

3.2.1.1 Gross energy savings

DNV's gross energy savings analysis is based on a two-stage modelling approach that estimates the effect of program measures on energy consumption of homes receiving the measures. The first stage uses site-level models to weather normalize energy consumption for the pre- and post-installation years. The second stage uses a difference-in-differences (DID) approach based on the pre-to-post difference of weather normalized energy consumption of participants and matched comparison households to estimate savings. The first-stage models control for the effect of weather on energy consumption while the second-stage models control for the effect of non-program changes on energy consumption.

The two-stage approach has a long track record in energy program evaluation and is attractive for a variety of reasons including:

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

This methodology is consistent with the approach laid out in the Uniform Methods Project (UMP) Chapter 8 modelling approach, which provides energy savings estimation protocols for energy efficiency interventions that have whole-home impacts like heat pumps.[8] It is also consistent with CalTRACK, which involved efforts to develop agreed upon steps for site-level modeling.[9] Details of the comparison group development, and first-stage and second-stage models are described in Appendix A: Consumption data analysis.

3.2.1.2 Net savings estimates

DNV did not field attribution surveys for the PY2021 PLA program. The intention was to collect data from participating distributors and utility customers for the heat pump water heater (HPWH) participants to be able to derive a net-to-gross ratio (NTGR) for HPWH only, however, due to the upstream program design, the evaluators were unable to install equipment to utility customers. No NTGRs were applied to the gross savings estimates for HPWH to arrive at net savings estimates.

No HVAC fuel substitution NTGR research was conducted since it was well-studied for this program under the PY2020 impact evaluation. Those results were adopted in the DEER Resolution currently under development, in addition to the forthcoming transition of the PLA program to a statewide design and implementation.

3.2.2 Source energy and CO_2 emissions savings

Source energy savings are the savings from only natural gas combustion, "either through power generation or in direct combustion for the end-use."[10] The CPUC approach considers "the source energy and emissions for renewable generation, such as solar, wind, and hydro-electric generation, to be zero."[11] Since "California does not have any non-natural gas fossil-fuel generation on the margin," [12] source energy savings are the savings only from natural gas combustion. Long-run source

8 National Renewable Energy Laboratory, "Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol," The Uniform Methods Project, nrel.gov, https://www.nrel.gov/docs/fy17osti/68564.pdf

9 CalTRACK, http://www.caltrack.org/

10 California Public Utilities Commission. Fuel Substitution Technical Guidance for Energy Efficiency Version 1.1. https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

11 Ibid.

12 Ibid.

energy factors that include the supply-side response to an increase in electricity load are used to estimate electricity source energy impacts. The source energy factors for electricity change over time as the projected generation mix changes, while the source energy factor for natural gas is constant. The methodology for calculating evaluated source energy savings follows the approach prescribed in the CPUC's Fuel Substitution Technical Guidance for Energy Efficiency Version 1.1. DNV inputted the reported and evaluated site-level gas and electricity energy impacts into the Fuel Substitution Calculator Version 1.1 for the determination of reported and evaluated source energy savings. DNV then extracted the (first year) full energy savings and lifecycle primary energy savings output values from the calculator for reporting the source energy impacts of the ductless and central HVAC fuel substitution measures.

Emissions savings in this case are "total CO_2 emissions over the EUL of the measure technology," as identified in the CPUC's Fuel Substitution Guideline document.[13] The lifecycle emissions savings (in CO_2 metric tons) output values were extracted from the calculator for reporting the emissions impacts of the ductless and central HVAC fuel substitution measures.

3.2.3 Participant characterization

DNV surveyed utility customers (end users) to gather data to characterize participation and understand the kinds of customers the programs are reaching. To assess the program's reach, DNV asked participants demographic questions including income, primary language, and educational attainment. DNV used the responses to assess the demographic distribution of customers, including the percentage of hard-to-reach (HTR) customers, renters, and those on CARE/FERA. In the survey, DNV also asked customers about their experience with the program including their level of satisfaction with various aspects of the program, their motivations for participating, barriers encountered, and resources used to inform their purchase decisions.

3.2.4 Bill impacts

A potential barrier to fuel switching could be the uncertainty regarding potential utility bill increases. DNV evaluated the bill impacts of the HVAC heat pump installations by combining the consumption data analysis results with rate schedule information from SCE and SCG. DNV assumed the same rate is applicable before and after retrofit to provide an apples-to-apples comparison of pre- and post-installation results. To assess gas bill impacts, DNV used SCG's residential service rates that apply to participating customers. SCG has two-tiered residential service rates for the residential gas service it provides. The two-tiered rates apply to baseline and non-baseline consumption. The majority of residential customers are on the individually metered residential gas service rate (GR), but DNV used the rate that is pertinent to each customer to calculate the cost impact of the gas use reduction from heat pump installations.

To assess electric bill impacts, DNV used SCE's residential service rates applicable to each participating customer. SCE's three-tiered domestic rates, which apply to three different usage levels, and time-of-use (TOU) rates, which vary by season and time of day, were relevant to customers included in the analysis. Additional information on the rate schedules used for calculating the bill impacts can be found in Cost effectiveness and Total System Benefit

DNV calculated the program's Cost Effectiveness Total Resource Cost (TRC) Ratio and Total System Benefit (TSB) based on evaluated impact results and presented them alongside the TRC and TSB based on the program's reported savings values for comparison. This analysis was conducted using the Cost Effectiveness Tool (CET) available on the CEDARS website. Presenting both reported and evaluated cost effectiveness provides stakeholders with a truing up of the program's delivered value under the existing tests while calculating the TSB benefits stakeholders with a benchmark for the upcoming portfolio transition to TSB. Since PAs are required to report TSB starting in 2022, providing TSB estimates for the PY2021

[13] Ibid.

programs such as PLA offers insights into a program's potential contribution to the overall energy efficiency portfolio in the future and necessary program design changes to better support lifecycle benefits.

4 RESULTS

4.1 Site energy savings

Site energy savings are the energy consumption reductions at the utility customer site and are the values SCE reports as savings. SCE reports both gross and net savings. Gross savings are the changes in energy consumption resulting from the installation of energy efficient technologies offered by PA programs, regardless of what factors may have motivated program participants to install these measures. Net savings are the portion of gross savings attributable to a program's influence.

4.1.1 Gross savings

Fuel substitution heat pump technologies provide both the heating and cooling needs of their installation. As fuel substitution measures, PLA intended for these heat pumps to replace end users' gas heating with efficient electric heating reducing the gas consumption of participating sites. While heat pumps reduce gas consumption, they are expected to increase electricity consumption associated with the need for heating. Electricity consumption at the sites can also increase when individuals use heat pumps for cooling at locations without prior cooling technologies.

DNV's gross energy savings analysis is based on a two-stage modelling approach that estimates the effect of program measures on energy consumption of homes receiving the measures. The first stage uses site-level models to weather normalize energy consumption. These models are required to put pre- and post-period consumption on a consistent weather basis (normalized annual consumption or NAC). They also provide useful information on heating and cooling consumption load components. The second stage uses a difference-in-differences (DID) approach based on the pre-to-post difference of weather normalized energy consumption of participant and matched comparison households to estimate savings. The first stage models control for the effect of weather on energy consumption while the second stage models control for the effect of non-program changes on energy consumption. The following sections present the results of the gross energy savings analysis in terms of normalized annual consumption (NAC) or whole home consumption and the heating and cooling consumption load components of whole home consumption.

4.1.1.1 Ductless HVAC fuel substitution technology group

DNV estimated the changes in annual weather normalized electricity and gas consumption of participating sites to evaluate the magnitudes of the decrease in gas and increase in electricity consumption from the installation of ductless heat pumps. Table 4-1 below illustrates the consumption change estimates. The results indicate a statistically significant but modest 3% annual savings in gas consumption. On the other hand, there is a statistically significant increase of 5% in annual electricity consumption. The savings in gas consumption is associated with an estimated 8% savings in gas heating load, while the annual increase in electricity consumption is associated with an estimated 26% addition in electric heating load. The modest electric cooling savings of less than 1% are statistically insignificant.

Table 4-1. Evaluated annual energy change per site for ductless HVAC fuel substitution technology

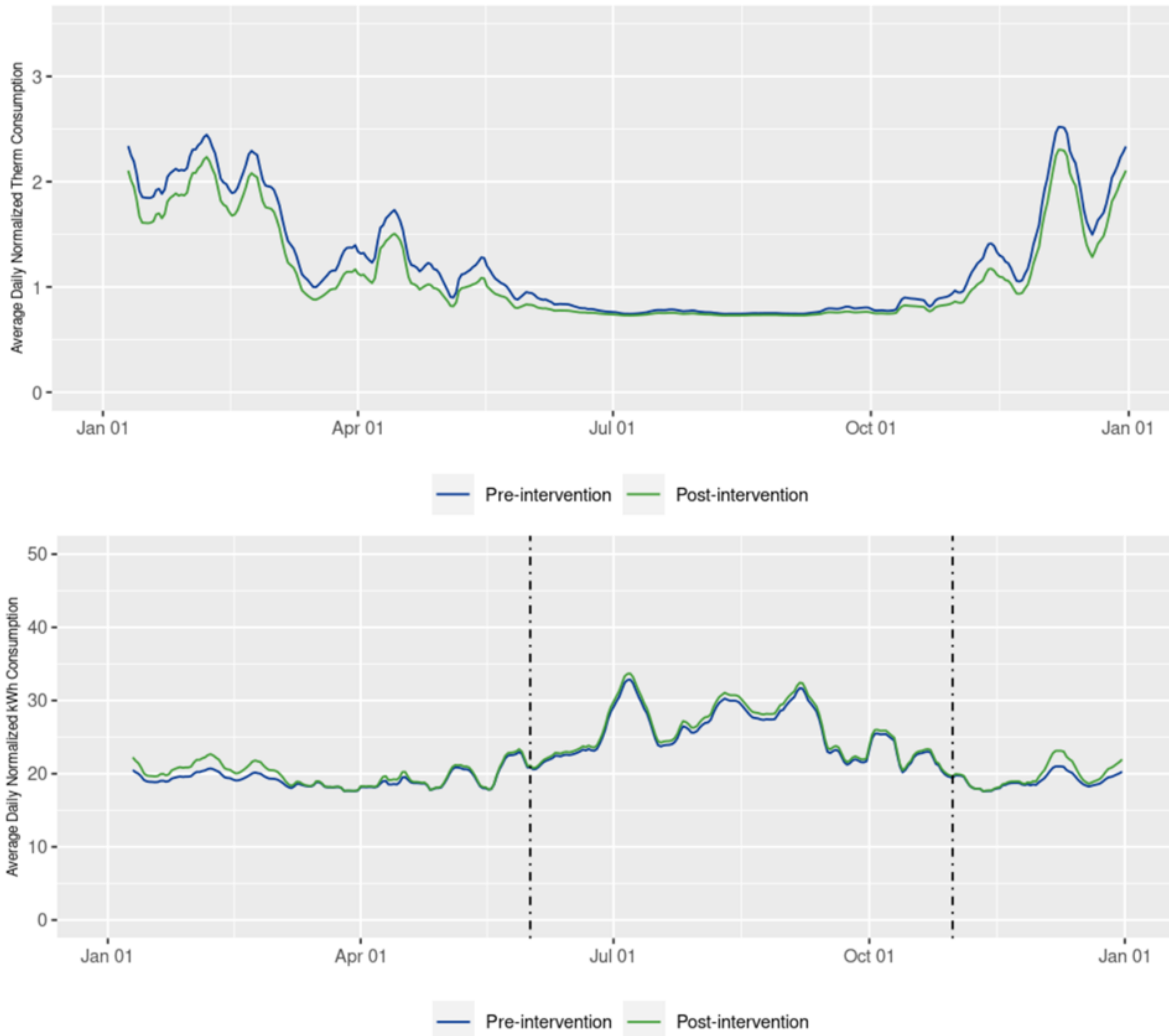
Fuel	Load component	Baseline consumption (therms)	Savings (therms)*	% Savings*	P-value	Relative precision**
Gas	**NAC**	**427**	**14**	**3%**	**0.00**	**37%**
	Heating load	164	13	8%	0.00	31%
Fuel	**Load component**	**Baseline consumption (kWh)**	**Savings (kWh)***	**% Savings***	**P-value**	**Relative precision****
Electric	**NAC**	**7,795**	**(369)**	**-5%**	**0.00**	**23%**
	Heating load	347	(91)	-26%	0.00	23%
	Cooling load	1,531	4	0%	0.85	898%

*Positive values indicate savings or a decrease in consumption and negative values indicate an increase in consumption.

**Relative precision values with 90% confidence
*** P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0 while the relative precisions indicate how certain the estimated changes are. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

Figure 4-1 provides the average daily weather normalized gas and electricity consumption pre- and post-installation of ductless heat pumps. The top panel illustrates the average daily normalized gas (therm) consumption, which shows a modest reduction in daily gas consumption during the heating season. The bottom panel illustrates the average daily normalized electricity consumption, which shows increases in average daily electricity consumption during the heating season (the period outside the two dashed vertical lines). While the daily gas consumption plot shows a modest reduction in daily gas consumption during the heating season, model estimates that consider the effect of exogenous change based on the DID model presented in the table above indicate the reduction in gas consumption from the installation of ductless heat pumps is less than shown. The DID model uses a comparison group to control the effect of non-program related changes that affect energy consumption trends. In this case, the comparison group controlled for a general downward trend in gas consumption.

Figure 4-1. Average daily normalized gas and electricity consumption pre- and post-installation of ductless systems



DNV combined the consumption data analysis and the survey results to compare consumption change estimates from the installation of ductless heat pumps for survey respondents that indicated that the ductless HVAC system replaced the existing heating and cooling systems with those that did not. Table 4-2 below provides the consumption change estimates for the survey respondents that indicated that the ductless HVAC system replaced the existing heating and cooling systems. These results indicate an 11% annual savings in gas consumption and a 12% increase in annual electricity consumption. As expected, the annual gas savings for ductless HVAC systems that replaced the existing heating and cooling systems are statistically significantly greater than those that did not. Greater gas savings are expected for ductless HVAC systems that replaced the existing heating and cooling systems compared to ductless HVAC systems that did not replace the existing heating and cooling systems, since ductless HVAC systems installed without replacing the existing systems are either load building or only partial displacement as opposed to fuel substitution. Despite annual gas savings that are 3 times greater than the overall ductless HVAC fuel substitution technology group, these annual gas consumption savings are still only about 20% of the reported savings.

Table 4-2. Evaluated annual energy change per site for ductless systems that replaced existing systems

Fuel	Load component	Baseline consumption (therms)	Savings (therms)*	% Savings*	P-value	Relative precision**
Gas	**NAC**	**390**	**44**	**11%**	**0.11**	**102%**
	Heating load	147	51	35%	0.02	70%
Fuel	**Load component**	**Baseline consumption (kWh)**	**Savings (kWh)***	**% Savings***	**P-value**	**Relative precision****
Electric	**NAC**	**7,338**	**(892)**	**-12%**	**0.01**	**61%**
	Heating load	475	(425)	-89%	0.00	55%
	Cooling load	1,134	89	8%	0.66	367%

*Positive values indicate savings or a decrease in consumption and negative values (in parenthesis) indicate an increase in consumption.
**Relative precision values with 90% confidence
*** P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0 while the relative precisions indicate how certain the estimated changes are. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

4.1.1.2 Central HVAC fuel substitution technology group

Table 4-3 provides the estimated gas and electricity consumption changes per site for central heat pump systems. The results indicate annual gas consumption savings of 25% and gas heating load savings of 50%. Annual electricity consumption increases by 9% with an electric heating load addition of more than 150% and cooling load reduction of 12% from the installation of central heat pumps. Gas consumption savings from central heat pumps are over seven times higher than such savings from ductless systems. However, the gas consumption savings are only about 50% of reported.

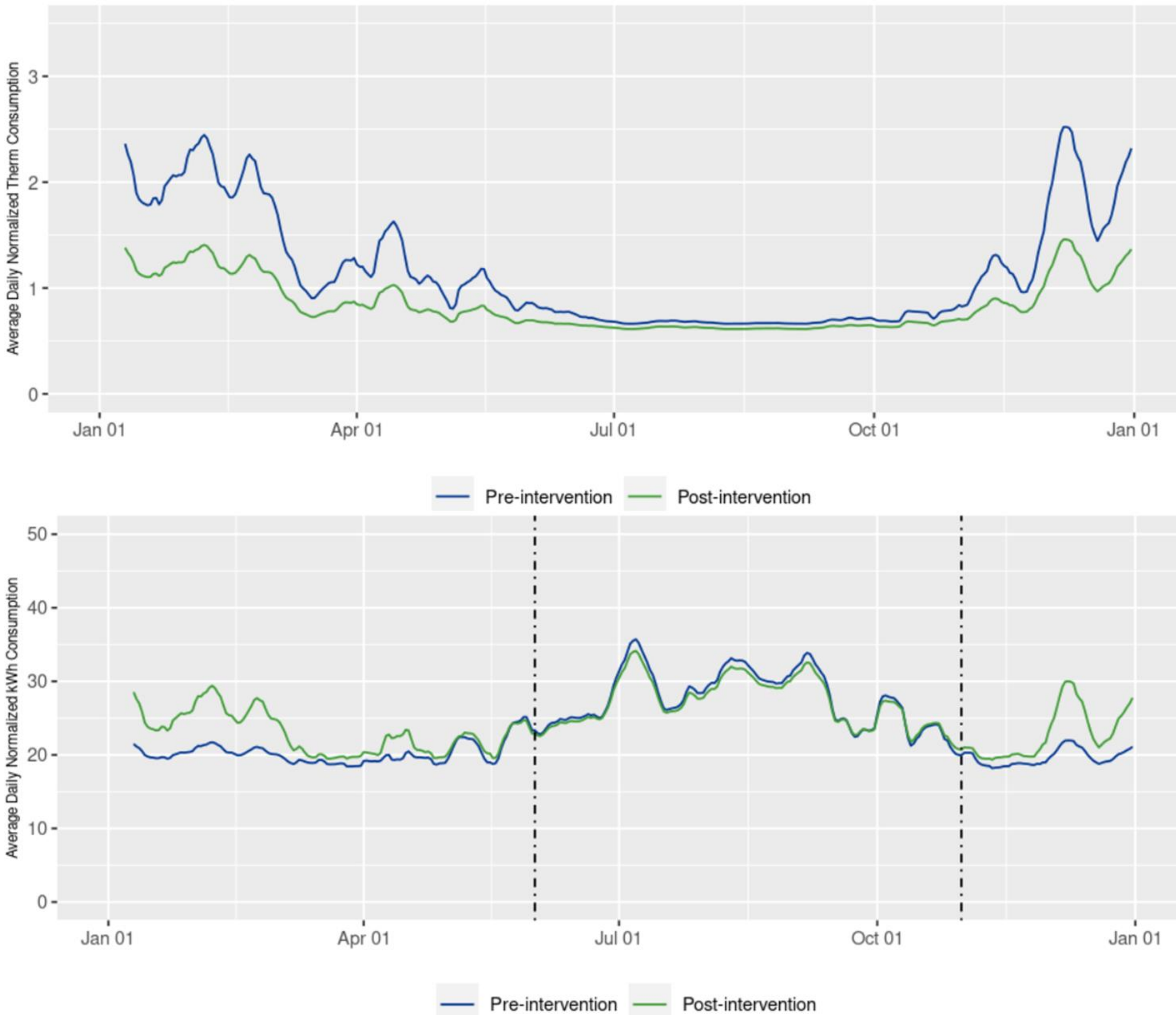
Table 4-3. Evaluated annual energy change per site for central HVAC fuel substitution technology

Fuel	Load component	Baseline consumption (therms)	Savings (therms)*	% Savings*	P-value	Relative precision**
Gas	**NAC**	**421**	**107**	**25%**	**0.00**	**14%**
	Heating load	171	85	50%	0.00	13%
Fuel	**Load component**	**Baseline consumption (kWh)**	**Savings (kWh)***	**% Savings***	**P-value**	**Relative precision****
Electric	**NAC**	**8,327**	**(739)**	**-9%**	**0.00**	**28%**
	Heating load	313	(502)	-160%	0.00	14%
	Cooling load	1,846	230	12%	0.00	51%

*Positive values indicate savings or a decrease in consumption and negative values indicate an increase in consumption.
**Relative precision values with 90% confidence
***P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0 while the relative precisions indicate how certain the estimated changes are. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

Figure 4-2 provides annual daily normalized gas and electricity consumption pre- and post-installation of central heat pumps. The top panel, presenting normalized gas consumption, makes evident the notable reduction in gas load during the heating season following the installation of central heat pumps. The bottom panel, showing normalized electricity consumption, shows the increase in electric load during the same time period. It also indicates the reduction of electric load during the cooling season. Like the ductless heat pump fuel substitution technology, the DID model used to estimate the gas load reduction associated with this technology controls for a general downward trend in energy consumption, which means the gas savings achieved from the central heat pumps are less than they appear to be in this plot.

Figure 4-2. Average daily normalized gas and electricity consumption pre- and post-installation of central systems



4.1.1.3 Residential HVAC heat pump replacement technology group

Table 4-4 provides the estimated gas and electricity consumption changes per site for HVAC heat pump replacements. The results indicate annual gas consumption savings of 15% and gas heating load savings of 29%. Annual electricity consumption increases by 4% with an electric heating load addition of 18% and a cooling load reduction of 3% from the heat pump replacements. The gas heating load savings and addition of electric heating load suggest that many of the HVAC heat pump installations are not replacing an existing heat pump. This is supported by the survey results, where 75% of respondents with an HVAC heat pump replacement indicated that the HVAC heat pump replaced a central furnace system. This implies that the program is not able to adequately identify fuel substitution at the individual customer level.

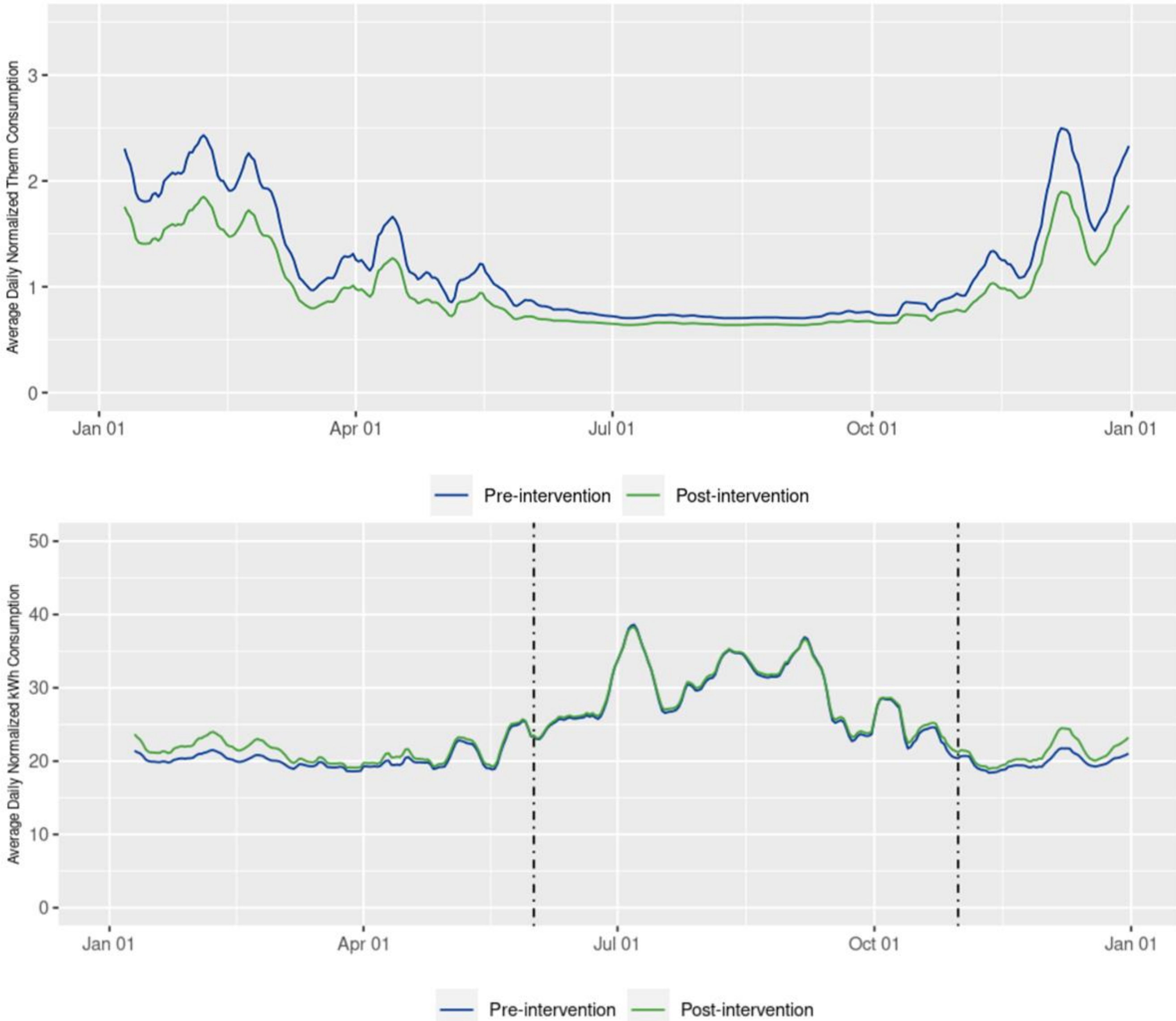
Table 4-4. Evaluated annual energy change per site for HVAC heat pump replacement technology

Fuel	Load component	Baseline consumption (therms)	Savings (therms)*	% Savings*	P-value	Relative precision**
Gas	**NAC**	**418**	**61**	**15%**	**0.00**	**42%**
	Heating load	158	46	29%	0.00	38%
Fuel	**Load component**	**Baseline consumption (kWh)**	**Savings (kWh)***	**% Savings***	**P-value**	**Relative precision****
Electric	**NAC**	**8,478**	**(369)**	**-4%**	**0.06**	**87%**
	Heating load	321	(58)	-18%	0.40	196%
	Cooling load	1,932	54	3%	0.63	346%

*Positive values indicate savings or a decrease in consumption and negative values indicate an increase in consumption.
**Relative precision values with 90% confidence
*** P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0 while the relative precisions indicate how certain the estimated changes are. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

Figure 4-3 provides annual daily normalized gas and electricity consumption pre- and post-installation of HVAC heat pump replacements. The top panel, presenting normalized gas consumption, makes evident the notable reduction in gas load during the heating season following the installation of heat pump replacements. The bottom panel, showing normalized electricity consumption, shows the increase in electric load during the same time period. It also indicates the reduction of electric load during the cooling season. Similar to the other HVAC heat pump technology groups, the DID model used to estimate the gas heating reduction associated with this technology controls for a general downward trend in energy consumption, which means the gas savings achieved from the heat pump replacements are less than they appear to be in this plot.

Figure 4-3. Average daily normalized gas and electricity consumption pre- and post-installation of heat pump replacements



4.1.1.4 Overall gross site savings

Table 4-5 compares the evaluated gas and electric savings per site against reported values for HVAC heat pump installations. The evaluated demand impacts for the ductless and central HVAC fuel substitution technologies are not shown in Table 4-5 since peak electric demand impacts are not recognized for fuel substitution technologies per the CPUC's policy outlined in the Fuel Substitution Technical Guidance Document. However, the evaluated demand impacts for each HVAC heat pump technology are provided in Appendix C: Analysis of peak demand impacts.

For HVAC heat pump fuel substitution installations, the evaluated electric consumption increases are about two-thirds of what is reported; gross realization rates (GRR) for the ductless and central HVAC heat pump fuel substitution measures are 85% and 69%, respectively. On the other hand, the ratios of evaluated to reported gas consumption savings are vastly different for the two HVAC heat pump fuel substitution technologies. Ductless HVAC fuel substitution heat pumps delivered only 6% of reported gas savings, while central HVAC fuel substitution heat pumps delivered 54% of reported gas savings.

For ductless HVAC heat pump installations, the high gross realization rate of reported electric consumption increases (85%) and low gross realization rate of reported gas savings (6%) indicate that many of the systems are not displacing gas heating systems but are building electric load by heating and cooling previously unconditioned spaces. This is supported by the participant survey results, where more than half of the participants indicated that the ductless heat pump did not replace the existing heating or cooling system. In fact, 40% of the participants indicated that the ductless heat pump was a new heating load. Additionally, more than one-third of the participants surveyed indicated that they used more heating and cooling after the ductless heat pump installation.

For the central HVAC fuel substitution heat pump installations, the similarity between the gross realization rate of reported electric consumption increases and the gross realization rate of gas consumption savings suggests that a component in the savings calculation is systematically overstated.

Residential HVAC heat pump replacements delivered none of the reported electric savings. In fact, the evaluated electric consumption increase is greater in magnitude than the reported electric savings. The evaluated electric demand increase is small relative to the reported demand savings resulting in a gross realization rate of -2%. Conversely, there were no reported gas savings for the residential HVAC heat pump replacements, while the evaluated annual savings was nearly 61 therms per site. Additionally, 75% of respondents with an HVAC heat pump replacement indicated that the HVAC heat pump replaced a central furnace system. This explains why the results for the heat pump replacement technology group appear similar to fuel substitution rather than heat pump replacement and implies that the program is not able to adequately identify fuel substitution at the individual customer level.

Overall, HVAC heat pump installations delivered 86% of reported electric consumption changes and 14% of reported gas savings.

Table 4-5. Reported and evaluated annual gross site energy change

Technology (Measure) group	Reported gross savings per site	Evaluated gross savings per site	GRR
Electric energy (kWh)			
Ductless HVAC – fuel substitution	-435	-369	85%
Central HVAC – fuel substitution	-1,077	-739	69%
Residential HVAC heat pump replacement**	353	-369	-104%
Total	**-486**	**-420**	**86%**
Electric demand (kW)			
Ductless HVAC – fuel substitution	-	-	-
Central HVAC – fuel substitution	-	-	-
Residential HVAC heat pump replacement**	0.220	-0.003	-2%
Total	**0.220**	**-0.003**	**-2%**
Gas energy (therms)			
Ductless HVAC – fuel substitution	237	14	6%
Central HVAC – fuel substitution	198	107	54%
Residential HVAC heat pump replacement**	-	61	-
Total	**222**	**32**	**14%**

*Positive values indicate savings or a decrease in consumption and negative values indicate an increase in consumption
**The Residential HVAC heat pump replacement technology group is not fuel substitution reporting electric impacts only without gas savings.

4.1.2 Net savings

Table 4-6 below provides a summary of the program's success in providing gas and electric savings at the utility customer's site through the heat pump technologies. The table presents evaluated net savings compared with the PA-reported net savings, and then in the last column, the net realization rate (NRR). The NRR removes the savings from installations that would have happened even if there were no incentives. NRR 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. In general, the higher the NRR value, the greater the program's achieved savings. However, because there are gas-to-electric fuel substitution measures, the electric impacts for these measures are not energy savings but energy consumption increases. Therefore, for fuel substitution a lower electric NRR and a higher gas NRR are desirable, and the ratio of gas energy savings to electric energy increases is important for the measure passing the fuel substitution test components.

Table 4-6. Reported / evaluated net attribution summary

Technology (Measure) group	Reported gross savings	GRR	Evaluated gross savings	Reported NTGR	Evaluated NTGR	Reported net savings	Evaluated net savings	NRR
	Electric energy (kWh)							
Ductless HVAC – fuel substitution	-2,406,485	85%	-2,044,107	100%	40%	-2,406,399	-817,643	34%
Central HVAC – fuel substitution	-974,286	69%	-668,359	100%	57%	-974,286	-380,965	39%
Residential HVAC heat pump replacement**	119,399	-104%	-124,638	60%	60%	71,639	-74,783	-104%
Heat Pump Water Heater – fuel substitution*	-174,840	100%	-174,840	100%	100%	-174,840	-174,840	100%
Total	**-3,436,212**	**88%**	**-3,011,944**	**101%**	**48%**	**-3,483,885**	**-1,448,230**	**42%**
	Gas energy (therms)							
Ductless HVAC – fuel substitution	1,310,954	6%	77,040	100%	40%	1,310,910	30,816	2%
Central HVAC – fuel substitution	179,287	54%	96,703	100%	57%	179,287	55,121	31%
Residential HVAC heat pump replacement**	0	-	20,553	-	60%	0	12,332	-
Heat Pump Water Heater – fuel substitution*	23,283	100%	23,283	100%	100%	23,283	23,283	100%
Total	**1,513,524**	**14%**	**217,579**	**100%**	**56%**	**1,513,480**	**121,551**	**8%**

*Due to the very limited information available from which to draw any conclusive independent findings regarding the presence or impacts of these Heat Pump Water Heater – fuel substitution measures, DNV was unable to produce evaluated savings or program attribution estimates and is passing through the claimed savings values. While it appears that the program followed the minimum data collection requirements for the program design (upstream), this left significant gaps in the evaluability of this technology group. Therefore, there remains considerable uncertainty about the validity and accuracy of the reported impacts and benefits of this technology.
**The Residential HVAC heat pump replacement technology group is not fuel substitution and represents electric only impacts and therefore did not report gas savings.

DNV applied last year's NTGR findings to the ductless and central HVAC fuel substitution measures. Due to the inability to evaluate the heat pump water heater fuel substitution measure and its small, reported savings relative to the PLA total reported savings, the reported gross savings, NTGR, and net savings for the measure were passed through for PY2021.

4.1.3 Program Attribution

From the PY2020 Plug Load and Appliance impact evaluation report[14], the NTGR is based on a triangulation of information from distributor, contractor, and customer surveys. For detailed net-to-gross methodology, please refer to Appendix F[15] within the PY2020 impact evaluation report.

Key findings for ductless mini-split systems include:

1) High-efficiency ductless heat pump sales increased by only 1% due to the program, as distributors faced challenges selling units due to low natural gas prices

2) The program had no effect on distributors' stocking or upselling practices, as they pass 100% of the rebates to buyers

3) Contractors reported that distributor recommendation (upselling) was the most important factor in attribution, while price was the least important

4) 31% of customers aware of the rebates would not have purchased the units without them, while 45% of unaware customers would have purchased the unit anyway, and 39% would have considered other options if their preferred unit was not in stock.

For central heat pump systems, findings include:

1) High-efficiency central heat pump sales increased by approximately 50% due to the program, the most significant market effect compared to ductless heat pumps

2) Distributors reported the program had minimal effect on their stocking or upselling practices, passing 100% of rebates to buyers, with rebates being a key factor in making sales

3) Contractors' responses for central heat pumps were similar to those for ductless heat pumps, with distributor recommendation (upselling) being the most important factor and price the least important

4) 18% of customers aware of the rebates would not have purchased the central heat pump units without them, while 20% of unaware customers would have purchased the unit anyway, and 35% would have considered other options if their preferred unit was not in stock.

4.2 Fuel substitution source energy savings

The evaluated source energy savings are based on the outputs of the CPUC's Fuel Substitution Calculator v1.1, using the total gross evaluated site energy savings and other pertinent measure details as the inputs. In reviewing the source energy savings, it is important to understand that in the fuel substitution test, "only the source energy from depletable fossil-fuel resources are considered"[16] by the CPUC. The CPUC approach considers "the source energy and emissions for renewable generation, such as solar, wind, and hydro-electric generation, to be zero." Since "California does not have any non-natural gas fossil-fuel generation on the margin," source energy savings are the savings only from natural gas combustion "either through power generation or in direct combustion for the end-use."[17] The calculator uses long-run source energy factors that include the supply-side response to an increase in electric load. The source energy factors "assume that supply-side

[14] CPUC_Group_A_HVAC_Fuel_Substitution_Impact_Evaluation_PY2020_Final, Section 4.1.2 https://www.calmac.org/publications/CPUC_Group_A_HVAC_Fuel_Substitution_Impact_Evaluation_PY2020_Final.pdf

[15] CPUC_Group_A_HVAC_Fuel_Substitution_Impact_Evaluation_PY2020_Final, Appendix F https://www.calmac.org/publications/CPUC_Group_A_HVAC_Fuel_Substitution_Impact_Evaluation_PY2020_Final.pdf

16 California Public Utilities Commission, "Fuel Substitution Technical Guidance for Energy Efficiency Version 1.1". https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

17 Ibid.

investments will be made such that the emissions intensity trajectory adopted in the CPUC's IRP Reference System Plan is maintained."

Table 4-7 below presents the evaluated and reported first-year full energy savings and the lifecycle source energy savings, in MMBtu for both the ductless and central HVAC fuel substitution technologies.

Table 4-7. Reported and evaluated first year and lifecycle source energy savings

Technology	First year full energy savings (MMBtu equivalent)		Lifecycle primary energy savings (MMBtu at generation source)	
	Per dwelling unit	Program total	Per dwelling unit	Program total
Ductless, evaluated	0.1	727	3.2	17,849
Ductless, reported	22.2	122,882	334.6	1,851,398
Ductless, ratio of evaluated to reported	**0.6%**	**0.6%**	**1.0%**	**1.0%**
Central, evaluated	8.2	7,389	125.0	113,107
Central, reported	16.1	14,603	245.7	222,358
Central, ratio of evaluated to reported	**50.6%**	**50.6%**	**50.9%**	**50.9%**

The results for ductless HVAC systems show a very small first year source energy savings of 0.1 MMBtu per household on average and 727 MMBtu in total, compared to the calculated reported equivalent of 22.2 MMBtu per household and 122,882 program total first year source energy savings. Lifecycle source energy savings, 3.2 MMBtu per household and 17,849 MMBtu total are also modest in comparison to the reported equivalent savings (334.6 MMBtu per household and 1,851,398 MMBtu total). As a result, ductless HVAC systems pass the source energy savings test[18] for fuel substitution. However, the evaluation finds the lifecycle source energy savings impact of this technology falls well short of meeting source savings expectations.

This first year result is driven by the low evaluated gas savings and the moderate evaluated electric consumption increase from the site-level savings analysis, whereas the lifecycle measurement benefits from the calculator's assumed lowering of electric source energy intensity (Btu/kWh) over the lifetime of the technology. The ductless HVAC systems will have to achieve higher gas savings in future program years to reach the source energy savings expected from these heat pump fuel substitution technologies.

Compared with the ductless HVAC technology group, the central HVAC technology group exhibits much greater first-year source energy savings of 8.2 MMBtu per household on average and 7,389 MMBtu in total. Therefore, the central HVAC technology group passes the source energy savings test for fuel substitution with a considerable margin. Relative to the reported first-year source savings of 16.1 MMBtu per household and 14,603 MMBtu for the program, the evaluated result for this technology comes much closer to meeting source savings expectations. However, the evaluated source energy savings are still only about 50% of expected. The central HVAC technology group falls short of expectations for source energy savings because the evaluation result does not achieve as much gas savings as expected, but it does achieve these gas savings at a lower electric energy increase than anticipated. The lifecycle source energy savings result for the central HVAC technology is also significant at 125 MMBtu per site and 113,107 MMBtu in total.

18 The threshold for passing is a positive (>0) lifecycle primary energy savings.

4.3 Fuel substitution CO_2 emissions savings

As with the source energy savings methodology, the evaluated carbon dioxide (CO_2) emissions savings are based on the outputs of the CPUC's Fuel Substitution Calculator v1.1 that use the total gross evaluated site energy savings and other pertinent measure data as the inputs. Emissions savings results are "total CO_2 emissions over the EUL of the measure technology," as identified in the CPUC's Fuel Substitution Guideline document.[19] Table 4-8 provides reported and evaluated CO_2 reductions at the per site and program levels for both the ductless and central HVAC fuel substitution technologies.

Table 4-8. Reported and evaluated lifecycle emissions savings

Technology	Lifecycle emissions savings (Metric tons CO_2)	
	Per dwelling unit	Program total
Ductless, evaluated	0.2	947
Ductless, reported	17.8	98,254
Ductless, ratio of evaluated to reported	**1.0%**	**1.0%**
Central, evaluated	6.6	6,003
Central, reported	13.0	11,801
Central, ratio of evaluated to reported	**50.9%**	**50.9%**

The emissions savings results are similar to the source energy findings in that the ductless HVAC systems produce a very small individual emissions benefit (0.2 tCO_2 evaluated versus the 17.8 tCO_2 reported) and very limited total emissions benefit given the volume of the reported systems. On the other hand, the central systems achieved a substantial reduction in lifecycle emissions (6.6 tCO_2 evaluated versus the 13.0 tCO_2 reported per site) per site as well as at the program level. However, the central systems only provide approximately 50% of the expected CO_2 reductions. This is a direct result of the difference in achieved gas savings between the ductless and central HVAC heat pump technologies. Like with the source energy savings findings, the ductless and central HVAC systems must achieve higher gas savings in future program years to reach the CO_2 emissions expected from these heat pump fuel substitution technologies.

4.4 Participant characterization

Table 4-9 shows a summary of household characteristics for participants who installed central heat pumps, ductless heat pumps, or replaced existing heat pumps as well as for the general population of California. The majority of central heat pump and heat pump replacement participants reported between $50,000 to $150,000 in annual income while most ductless heat pump participants reported more than $150,000 in annual income. However, ductless heat pump participants also reported the highest frequency (19%) of income less than $50,000 of any group. Additionally, the participants with ductless systems reported being enrolled in a discounted utility rate like CARE or FERA at twice the frequency of the central or heat pump replacement participants. While all participants reported high levels of home ownership, ductless heat pump participants were the only group to report renting their homes (1%). Ductless heat pump participants also reported the highest number of primary household languages that were not English (7%). This further suggests there may be greater

19 California Public Utilities Commission, "Fuel Substitution Technical Guidance for Energy Efficiency Version 1.1.," https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency

diversity in the ductless heat pump group than in the other two. Higher proportions of participants reported household incomes over $150,000 as compared with the general population of California, indicating program participants tend to be slightly more affluent.

Participants across all types reported being highly educated, with more than half reporting college or higher levels of educational attainment. By comparison, 35% of Californians have a bachelor's degree or higher, indicating that a disproportionate level of educated households is represented in the program. At least half of participant households who received central heat pumps or heat pump replacements include people over the age of 65 whereas the households that received ductless heat pumps were likely to have people under 18 and 65.

Table 4-9. Household characteristics: Income, education, age of household, ownership, primary language, CARE/FERA, DAC, and HTR

Characteristics	PY 2021 Central heat pump participants (n=117)	PY 2021 Ductless heat pump participants (n=380)	PY 2021 Heat pump participants (n=39)	California general population[20]
	a	b	c	
Income				
Less than $50,000	14%[b]	19%	13%	30%
More than $50,000 and less than $150,000	47%[b]	36%[c]	54%[a]	45%
More than $150,000	40%[b]	44%[c]	33%[a]	25%
Education				
College or higher	81%[b]	71%	69%[a]	45%
High school or less	13%	13%	17%	25%
Household				
Contains people under 18	38%[b]	41%[c]	36%	34%
Contains people over 65	53%[b]	45%[c]	62%[a]	30%
Ownership				
Own	100%[b]	99%[c]	100%	56%
Rent	0%	1%	0%	44%
Primary language				
English	95%[b]	93%[c]	97%[a]	56%
Language other than English	5%	7%	3%	44%
Chinese (including Mandarin and Cantonese)	2%	1%	3%	-
Spanish	2%	4%	0%	28%
Other	1%	1%	0%	16%

20 Income: U.S. Census Bureau, data.census.gov, https://data.census.gov/table?q=household+income&g=0400000US06&tid=ACSST1Y2021.S1901; Education, household Age, Ownership, Primary Language: U.S. Census Bureau, data.census.gov, https://data.census.gov/table?tid=ACSDP5Y2021.DP02&g=0400000US06;CARE/FERA: Utility Customer Information System (CIS) data; DAC: CalEnviroScreen, CalEPA; HTR: Calculated value based on CalEnviroScreen, metro area definition from the U.S. Office of Management and Budget (USOMB), CARE from utility CIS data, language and rental status from the American Community Survey (ACS) of the U.S. Census Bureau

Characteristics	PY 2021 Central heat pump participants (n=117)	PY 2021 Ductless heat pump participants (n=380)	PY 2021 Heat pump participants (n=39)	California general population[20]
	a	b	c	
Vietnamese	0%	1%	0%	-
CARE/FERA				
Enrolled in discounted utility rate (CARE or FERA)	6%[b]	10%	5%	25%
DAC				
DAC	17%[b]	22%[c]	13%	22%
Hard-to-reach				
Hard-to-reach	3%	4%	3%	34%

Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column
1 - Answers from a subset of respondents (n = 81 (central); n = 242 (ductless); n = 24 (heat pump)) who did not skip the question.
2 - Answers from a subset of respondents (n = 94 (central); n = 282 (ductless); n = 29 (heat pump)) who did not skip the question.
3 – Census data is not broken out into same languages as the participant survey. All languages other than Spanish and English for California's general population are captured in "other."

Hard-to-reach (HTR) customers are defined as meeting the criteria that they live in a disadvantaged community (DAC) as defined by CalEPA in addition to meeting one of the following criteria: a primary language other than English spoken in the home, multifamily or mobile home tenancy (renting or leasing), or income qualifying for CARE or FERA.[21] Currently, less than a quarter of participants (17% for central, 22% for ductless, and 13% for replacement) live in DACs. Using the HTR criteria, only 3-4% of participants reported responses that would qualify them as such. When compared to the general population of California, participants across all measure types are more likely to have English as the primary language, more likely to own their homes, less likely to be enrolled in CARE or FERA, less likely to live in DACs (except for ductless participants), and less likely to be considered hard-to-reach. While this shows the program does not currently reach underserved populations, it does not specifically target reaching HTR customers as it uses upstream and midstream delivery types.

4.5 Bill impacts

The results of the bill impact assessment are presented in Table 4-10. Central HVAC systems that replaced less efficient heating systems afforded utility customers an average annual bill savings of $89. Ductless systems that supplemented existing HVAC equipment led to an average annual bill savings of $31. Average annual bill savings for ductless HVAC systems were driven by smaller increases in electric cooling load and greater savings in gas consumption relative to PY2020. The gas bill savings associated with each technology outweighed cost increases from their increased electric load. Overall, the program resulted in an average annual bill savings of $46 and a total bill savings of $307,505.

21 California Public Utilities Commission, CARE/FERA Program, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/care-fera-program

Table 4-10. SCE PLA PY2021 bill impacts assessment

Technology	Average annual bill impact			Total participants	Total bill impact
	Electric	Gas	Total		
Ductless HVAC	$55	-$86	-$31	5,533	-$169,816
Central HVAC	$141	-$230	-$89	905	-$80,493
Residential HVAC heat pump replacement	$55	-$165	-$110	338	-$37,276
Overall	**$67**	**-$113**	**-$46**	**6,711**	**-$307,505**

Negative values indicate a cost reduction while positive values indicate an increase.

For comparison, DNV calculated the average equipment cost for each technology. The average equipment cost was calculated as the retail price of the equipment minus incentives and does not include installation costs. The average equipment cost for ductless HVAC systems, central HVAC systems, and residential HVAC heat pump replacements was $534, $2,728, and $961, respectively. In each case, the average equipment cost exceeds the bill savings over the expected useful life of the equipment.

The results of the bill impact assessment for participating customers enrolled in CARE or FERA are presented in Table 4-11. The gas bill savings associated with each technology outweighed cost increases from their increased electric load for these utility customers. While the magnitude of the average annual gas bill savings and electric bill increases tend to be smaller for CARE / FERA utility customers relative to all participating customers, the magnitude of the average annual total bill savings is similar. Since customers enrolled in CARE or FERA tend to have lower baseline consumption, gas consumption savings, and electric load, increases tend to be less. Overall, the program resulted in an average annual bill savings of $41 and a total bill savings of $72,238 for participating customers enrolled in CARE or FERA.

Table 4-11. SCE PLA PY2021 CARE/FERA bill impacts assessment

Technology	Average annual bill impact			Total participants	Total bill impact
	Electric	Gas	Total		
Ductless HVAC	$30	-$68	-$37	1,344	-$57,391
Central HVAC	$107	-$159	-$53	119	-$7,743
Residential HVAC heat pump replacement	$65	-$121	-$56	89	-$6,615
Overall	**$38**	**-$79**	**-$41**	**1,524**	**-$72,238**

Negative values indicate a cost reduction while positive values indicate an increase.

4.6 Cost effectiveness and Total System Benefit

The evaluators calculated the program's cost effectiveness (CE) based on evaluated savings using the Cost Effectiveness Tool (CET) available on the CEDARS website. Table 4-12 summarizes the PY2021 SCE PLA program electric and gas savings benefits and the total resource costs associated with these benefits.

Table 4-12. PLA program benefits and costs, PY2021

Program	Electric benefit	Gas Benefit	Program TRC cost
Plug Load and Appliances (SCE-13-SW-001B)	-$3,000	$1,499,108	$13,528,385

The ratio of the combined benefits to the total resource cost quantifies the cost effectiveness of the programs and is summarized by the total resource cost (TRC) ratio.[22]

We compared the evaluated TRC values with claimed TRC values for the PLA program filed in CEDARs. We present these values in Figure 4-4. The claimed values filed by the programs were above one. The evaluated TRC values are a fraction of the claimed values and reflect the low gross realization rates associated with the installed measures.

Figure 4-4. Claimed and evaluated TRC ratios, PY2021

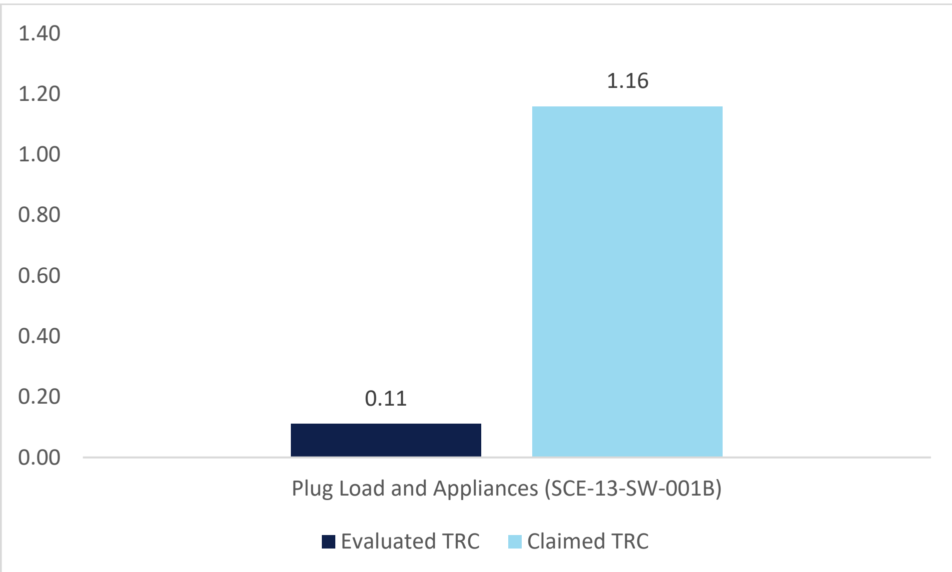


Table 4-13 looks at the system benefits for the PLA program. The evaluated gas system benefits relative to those based on claimed values were higher than the electric system benefits relative to those based on claimed values. The evaluated electric system benefits were negative which implies there was an overall electric load added. The program had a realization rate of 8% for total system benefits.

Table 4-13. Total system benefits of PLA program, PY2021

Claimed	Evaluated	Realization Rate
Electric		
$348,753	-$3,000	-1%
Gas		
$18,921,516	$1,499,108	8%
Total		
$19,270,268	$1,496,107	8%

22 The Total Resource Cost (TRC) Test is a measure of cost-effectiveness that compares the net benefit of programs to their net cost. https://docs.cpuc.ca.gov/published/FINAL_DECISION/105926-03.htm

4.7 System attributes and participant experience

4.7.1 Heating system attributes

A summary of the attributes of the previous and the new heating systems as well as participant behavior related to both is provided in Table 4-14. Most participants reported the installed heat pumps were still in use (90% for replacements, 94% for ductless and central). Most participants also reported they had utility gas, suggesting households have yet to be completely electrified despite the addition of a heat pump.

The results also show that most central (93%) and replacement heat pump (82%) participants reported replacing an existing system. However, only 52% of ductless heat pump recipients replaced an existing system. Ductless heat pump participants frequently reported a purpose for installation that would result in adding a new heating load (40%). These participants reported installing heat pumps in previously unheated spaces (13%), adding heat pumps without removing existing systems (13%), installing them in a new room added to the home (6%), and adding to improve comfort (9%). The low gas savings estimated for those with ductless heat pumps reflect this limited fuel substitution and apparent load building by this group of participants. Additionally, a greater proportion (38%) of ductless system recipients as compared to the other two groups reported using more heat after installing their heat pumps.

Previous and existing heating systems for both central and replacement heat pump participants were largely central furnace systems (67% and 75% respectively). On the other hand, ductless heat pump recipients reported that they had a central furnace system in a much lower proportion (36%). Additionally, nearly half of participants reported their existing system worked well which indicates a high incidence of early replacement.

Table 4-14. Heating system characteristics and changes

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump replacement participants (n=39)
	a	b	c
Heating system			
Heat pump still in use	94%	94%[c]	90%[a]
Homes with gas service	91%[b]	81%[c]	90%
Percent utility gas	86%[b]	73%[c]	85%
Percent propane	4%[b]	8%	5%
Replacing existing heating system	93%[b]	52%[c]	82%[a]
New heating load	1%	40%[c]	8%
Installed in previously unheated space	0%	13%	0%
Installed in a new room added to home	0%	6%	3%
Added without removing existing system	0%	13%	3%
Added to improve comfort	1%	9%	3%
Previous heating system[1]			
Central furnace system	67%[b]	36%[c]	75%[a]
Existing heat pump system	18%[b]	7%[c]	17%

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump replacement participants (n=39)
	a	b	c
Heating system			
Floor/wall heater	3%[b]	19%	0%
Previous heating system did not work well	35%[b]	23%[c]	46%[a]
Previous heating system worked well	51%[b]	54%[c]	46%
New heat use[1]			
More heat use	19%[b]	38%[c]	13%
About the same heat use	59%[b]	31%[c]	58%
Less heat use	10%	11%[c]	21%[a]
Old System Use[2]			
Using old system more than 50% of the time	NA	19%	0%
Using old system 25-50% of the time	NA	53%	100%
Using old system less than 25% of the time	NA	28%	0%

1 - Answers from a subset of respondents (n = 91 (central); n = 271 (ductless); n = 24 (heat pump)).
2 - Answers from a subset of respondents (n =0 (central); n = 36 (ductless); n = 1 (heat pump)).
Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column

4.7.2 Cooling system attributes

A summary of the attributes and the previous and new cooling systems is in Table 4-15. As the table indicates, most central and replacement heat pump participants reported replacing an existing system (79% central and 74% replacement) whereas 64% of ductless participants indicated adding a cooling load. These results further explain the findings that central heat pumps were achieving higher savings compared to ductless systems. Ductless system participants reported more frequently added to existing systems and using more cooling (43%) after heat pump installation as compared to central heat pump participants.

Participants who installed central heat pumps or replaced heat pumps were most likely to have already had central a/c as their ac system. Ductless heat pump participants, however, reported more than any other group (36%) that they did not have a cooling system to begin with. This, coupled with far more ductless heat pump participants reporting using more cooling after installation, helps explain why ductless heat pumps received low savings.

Even though 64% of ductless heat pump participants reported adding a heat pump without removing the existing system, the majority (89%) reported they used their old system rarely, if ever, when needing to cool their homes. Across all participants who added to instead of replacing their existing system, old systems were reported to be infrequently used.

Table 4-15. Cooling system characteristics and changes

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump participants (n=39)
	a	b	c
Cooling system			
New cooling load	10%[b]	64%[c]	18%[a]
Replacing existing cooling system	79%[b]	24%[c]	72%[a]
Previous cooling system[1]			
Central A/C	75%[b]	30%[c]	71%[a]
Window or portable A/C	2%[b]	14%	11%[a]
Heat pump A/C	8%	8%	6%
Did not have a cooling system	6%[b]	36%[c]	11%
Old A/C not working well	35%[b]	21%[c]	43%[a]
Old A/C working	55%[b]	44%[c]	49%[a]
New cooling use[2]			
More cooling use	23%[b]	43%[c]	29%
About the same cooling use	62%[b]	38%[c]	43%[a]
Less cooling use	10%[b]	14%[c]	21%[a]
Old system use[3]			
Using old system more than 50% of the time	0%	8%	14%
Using old system 25-50% of the time	0%	4%	0%
Using old system less than 25% of the time	100%[b]	89%	86%[a]

1 - Answers from a subset of respondents (central (n=104), ductless (n=336), heat pumps (n=35)
2 - Answers from a subset of respondents (central (n=92), ductless (n=93), heat pumps (n=28) who replaced their old system
3 - Answers from a subset of respondents (central (n=12), ductless (n=239), heat pumps (n=7) who kept their old system
Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column

4.7.3 Participant experience

We surveyed participants to understand their experience with various aspects of their participation in the program and have presented the results below in Table 4-16. Participants across all HVAC measures were the most satisfied with their contractors and equipment, with heat pump replacement participants showing the highest satisfaction overall. Participants were the least satisfied with savings, with central heat pump participants showing the lowest satisfaction (58%). Despite the lower satisfaction with savings, only a quarter (20-28%) of participants across all HVAC measures reported noticing their energy costs increase. In fact, most participants across all HVAC measures reported noticing their energy costs decrease at least a little to a lot. Central and heat pump replacement participants reported slightly higher perceived energy cost decreases than those with ductless systems. This perception of slightly more savings is consistent with DNV's estimates indicating that on average central participants saved $55 while ductless participants saved $23 annually.

Table 4-16. Participant satisfaction and energy costs

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 heat pump replacement participants (n=39)
	a	b	c
Satisfaction			
Satisfaction overall	79%[b]	76%[c]	82%[a]
Satisfaction with contractor	79%[b]	77%[c]	85%[a]
Satisfaction with equipment	79%	79%[c]	85%[a]
Satisfaction with savings	58%[b]	62%	64%[a]
Reported change in annual energy costs			
Noticed energy costs increase a lot	11%[b]	9%[c]	15%
Noticed energy costs increase a little	9%[b]	14%	13%
Noticed energy costs decrease a little	28%[b]	25%	26%
Noticed energy costs decrease a lot	15%[b]	10%[c]	15%
Did not notice a change in energy costs	16%[b]	15%	5%

Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column

Table 4-17 provides the motivations and barriers reported by participants. A majority of central heat pump participants (61%) and heat pump replacement participants (54%) reported saving money and incentives as motivating their installations while the highest reported motive for ductless heat pump participants was to improve safety and comfort (49%). Over a third (36%) of ductless heat pump participants also reported adding air conditioning as a motive for installation, higher than the other two measure groups. Other top motivations for central heat pump and heat pump replacement participants were saving energy/ reducing carbon emissions and based on recommendation. Many of the groups reported experiencing no barriers or challenges related to their heat pump installation. Installation and cost were the top two barriers reported amongst respondents across all groups.

Table 4-17. Participant motivations and barriers

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump replacement participants (n=39)
	a	b	c
Motivations			
Save money/incentives	61%[b]	38%[c]	54%[a]
Save energy/reduce carbon emissions	59%[b]	42%[c]	59%
Based on recommendation	37%[b]	27%[c]	44%[a]
Improve safety and comfort	35%[b]	49%[c]	33%
Better use of renewable energy	32%[b]	21%	23%[a]
Equipment failure or renovation	24%	23%	26%

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump replacement participants (n=39)
	a	b	c
Based on reputation or previous experience with heat pumps	12% [b]	15%	10%
Adding A/C	9% [b]	36% [c]	18% [a]
Barriers			
No barriers or challenges	53% [b]	50% [c]	54%
Installation barriers	15% [b]	18% [c]	26% [a]
Cost barriers	19% [b]	17%	15%
Availability of equipment	2%	3%	8%
Knowledge barrier	8% [b]	4%	3%
Qualified contractors	0%	3%	5%

Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

Most participants across all measure groups reported contractors as the main influence in making their purchase decisions. Using contractor recommendations could be linked to the high satisfaction across all groups for contractors and equipment. Other top resources include brand reputation and web search. Table 4-18 shows all the reported resources used by participants. Prior experience had limited influence across all groups, with the lowest for people who replaced existing heat pumps.

Table 4-18. Participant resources used to inform purchase decision

Characteristics	PY2021 Central heat pump participants (n=117)	PY2021 Ductless heat pump participants (n=380)	PY2021 Heat pump participants (n=39)
	a	b	c
Resources used to inform purchase decision			
Contractor	61%[b]	55%[c]	59%
Brand or reputation of manufacturer	34% [b]	26%[c]	33%
Web search	32% [b]	21%[c]	28%[a]
Utility program/marketing	17% [b]	10%[c]	15%
Manufacturer website	16%	15%	13%
Friend / family	15% [b]	20%[c]	8%[a]
Prior experience	7% [b]	14%	3%

Note: Letter superscript denotes value is statistically significantly different, at least at the 90% confidence level, from the value in the referenced column

5 FINDINGS AND RECOMMENDATIONS

5.1 Program documentation

Finding: The breadth of the HVAC measure documentation data was sufficient, but the quality could be improved.

- **Recommendation**: SCE and its implementers should increase efforts to train participating midstream program distributors on consistent and accurate data recording.
- **Recommendation**: SCE and its implementers should conduct regular quality control reviews of the data prior to submittal.
- **Recommendation**: SCE and its implementers should design program documentation to include the PA's premise and customer identifier fields.
- **Recommendation**: SCE and its implementers should collect more site and contact information linking program data to utility customer database information to help benefit the certainty of evaluated savings.

5.2 Gross savings

Finding: Ductless HVAC fuel substitution measures fell short of expectations for gas savings. This is in part because, as survey respondents indicate, the ductless heat pump measure is not often replacing an existing gas heating system, but the analysis also shows this doesn't account for all the unachieved gas savings. Combining the consumption analysis and the survey results indicates that on average, when the ductless HVAC system does replace an existing heating system, the gas savings are 19% of reported for those claims.

- **Recommendation**: A best practice for SCE would be to implement program controls to track if claims are offsetting existing gas heating systems.
- **Recommendation:** The gross savings for the ductless HVAC technology should be reviewed considering the poor achieved gas savings from consecutive (PY2020 and PY2021) impact evaluations.

Finding: The claimed DHW measure installations were not verifiable and their gross impacts (site energy, source energy, and emissions) remain untested and uncertain due to the extremely limited available data collected by the program's upstream delivery type. Evaluators were unable to associate equipment installations to the site or ensure installations were within service territory.

- **Recommendation:** In the future, SCE should consider a midstream program design for DHW, with data collection processes similar to the ductless HVAC fuel substitution program. This will help collect reliable and higher quality equipment details, market actors' contact information, and increase efforts to ensure the program installs heat pump water heater claims within the service territory.

6 APPENDICES

6.1 Appendix A: Consumption data analysis

This section provides the details of the two-stage consumption data analysis approach DNV used to estimate the impact of fuel substitution heat pumps.

6.1.1 First stage models

In the first stage, DNV estimates individual daily regression models of energy consumption for all customers in the residential analysis population. The models estimate consumption as a function of heating and cooling degree days, using daily data. Consistent with PRISM and CalTRACK, these models identify the heating and cooling degree day base that supports the best, most informed model. This individualized, site-level approach produces models that reflect the unique heating and cooling consumption dynamics of a house and its occupants. These models are required to put pre- and post-period consumption on a consistent weather basis. They also provide useful information on heating and cooling consumption.

The first stage regression model used to estimate the effect of weather on energy consumption is given by:

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

Where:

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

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

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

β_0, β_h, β_c – Site-level regression coefficients measuring intercept (base load), heating load, and cooling load, on a single year's energy consumption, respectively

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

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

ε_{im} – Regression residual

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

Model parameter estimates for each site allow the prediction of site-level consumption under any weather condition. For evaluation purposes, all consumption is put on a typical weather basis, using CZ2022 TMY values, and produces an estimate referred to as normalized annual consumption (NAC). NAC for the pre- and post-installation periods are calculated for each site and analysis time frame by combining the estimated coefficients $\hat{\beta}_h$ and $\hat{\beta}_c$ with the annual typical meteorological year (TMY) degree days H_0 and C_0 calculated at the site-specific degree-day base(s), $\hat{\tau}_h$ and $\hat{\tau}_c$. NAC is given by:

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

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

For each home in the analysis, NAC is determined separately for the pre- and post-installation years, and the pre-post difference ΔNAC_i is calculated. Pre- to post-installation changes in weather normalized energy use were the basis of the second stage DID models.[23]

6.1.2 Comparison group

The impact evaluation follows site-level billing analysis methodologies to provide valid estimates of changes in gas and electric consumption for program participants. A key challenge for this kind of study is establishing the correct baseline from which to quantify change. The industry-accepted and recommended approach combines pre-installation data and a matched comparison group to produce a baseline that accounts for non-program-related change occurring during the evaluation timeframe.

Developing a well-matched comparison group for the participants is essential to the impact evaluation's success. It involves the identification of non-participant households that are similar to participants in relevant observable characteristics within certain strata including climate zone and housing type. Matching is an art that balances the number and complexity of matching variables with the level of stratification.

DNV constructed matched comparison groups from general population customers for the analysis. This effort involved two phases. The first phase identified 20 households for every participant with similar energy use levels (based on monthly electric and gas billing data) within strata defined by climate zone. In the second phase, DNV identified 1-to-1 matches based on interval consumption data and chose the optimal match for each participating site from the initial matches.

In all cases, matching models included annual energy use, the ratio of summer-to winter energy use for gas, the ratio of summer-to-shoulder and winter-to-shoulder use for electricity to account for seasonality, and peak demand. For electricity, DNV used the level of energy consumption at 6 p.m. for identified 'heat wave' periods to capture peak demand conditions. 'Heat wave' periods were identified for climate zones with participating residential customers for weekdays between June through September where most customers had their maximum 6 p.m. kWh. For gas, DNV used daily energy use for identified 'cool wave' periods to capture peak demand conditions. Such periods were identified for weekdays between December and February for the same climate zone.

For both gas and electricity matching, DNV also used tenure as an additional matching variable. Tenure was included as a proxy for trend in energy use and defined as the length of time, measured in years, that a customer has resided at a premise.

DNV used Mahalanobis minimum distance matching without replacement for all matches used in the analysis. Mahalanobis distance matching is scale-invariant and considers correlations of covariates to generate well-balanced matches. Balance is tested using standardized mean differences, the ratio of the variance of participants 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

23 These models were also used to determine and exclude outliers based on statistical tests; DID values exceeding pre-defined studentized residual limits were considered outliers and excluded from the second stage DID models.

standardized mean differences and the ratio of their variances for the matched groups. The standardized mean difference is given by:

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

A standardized mean difference value that exceeds 0.2 shows extreme imbalance, while the closer to 0 this value gets, the better the condition of matching. For the variance ratio, a value close to 1 indicates balance while values that are 0.5 or less and 2 or greater indicate extreme imbalance.[24]

6.1.3 Second-stage models

DNV estimated program impacts with a second-stage model that compares the pre- and post-installation site-level normalized annual consumption (NAC) between participants and comparison households. DNV produced the NACs with the site-level models and then capture the change in NAC between pre- and post-installation periods (∆NAC). Comparison group ∆NAC provides a proxy for the non-program change occurring between the two time-periods. This is a simple but robust model that can be estimated for geographical areas, consumption groupings, or within any of the dimensions defined in the population characterization process. The changes in consumption for each program and measure provide the basis for carbon calculations.

The precision of the program-wide savings estimates is a function of the number of participants who can be incorporated into the analysis. Consumption data analyses for a program of this size estimating changes of this magnitude are expected to provide results with good relative precisions. While the analysis requires a year of pre- and post-installation data, the availability of AMI data makes it possible to ease this requirement to 90% of pre- and post-period allowing the retention of data from more customers. For participants, a full year of post-period gas data will not be required reflecting the transition in full or in part to electricity to power the home's end uses.

Pre- and post-program periods are based on a definition of a blackout period for each participant. According to CalTRACK, an intervention period is a "time between the end of the baseline period and the beginning of the reporting period in which a project is being installed." It advises the use of "the earliest intervention date as project start date and the latest date as the project completion date."[25] DNV used a 1-month blackout period for each site based on the reported installation date in the detailed tracking data provided by SCE.

The pre-to-post installation difference in NAC or DID model used to model whole-home energy changes is given by:

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

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

6.1.4 First- and second-stage model results

In this section, DNV presents all second stage DID model results starting with those used to evaluate ductless and central HVAC heat pump fuel substitution installations followed by models used to evaluate HVAC heat pump replacements. Each table provides the estimated baseline consumption and DID estimate for normalized annual consumption (NAC) and each load component. Results include model estimates, their standard errors, p-values,[26] and the number of participants whose

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

25 CalTrack, "CalTRACK Methods," docs.caltrack.org, http://docs.caltrack.org/en/latest/methods.html#section-1-overview

26 P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

data is included in the model. Results in Section 4.1.1 including savings and load increase are based on the values provided in these tables.

Table 6-1 provides electric NAC, heating, and cooling model results for the ductless HVAC fuel substitution technology group.

Table 6-1. Electric NAC, heating, and cooling savings models for ductless HVAC fuel substitution technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	2,693	7,795	96	0.00
		Treatment	2,693	415	138	0.00
	DID	Intercept	2,693	131	29	0.00
		Treatment	2,693	(369)	52	0.00
Heating load	Baseline load	Intercept	2,685	347	10	0.00
		Treatment	2,685	108	16	0.00
	DID	Intercept	2,685	14	8	0.07
		Treatment	2,685	(91)	13	0.00
Cooling load	Baseline load	Intercept	2,653	1,531	34	0.00
		Treatment	2,653	25	48	0.60
	DID	Intercept	2,653	(52)	14	0.00
		Treatment	2,653	4	23	0.85

Table 6-2 provides electric NAC, heating, and cooling model results for the central HVAC fuel substitution technology group.

Table 6-2. Electric NAC, heating, and cooling savings models for central HVAC fuel substitution technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	452	8,327	242	0.00
		Treatment	452	733	345	0.03
	DID	Intercept	452	170	68	0.01
		Treatment	452	(739)	127	0.00
Heating load	Baseline load	Intercept	450	313	26	0.00
		Treatment	450	513	43	0.00
	DID	Intercept	450	80	24	0.00
		Treatment	450	(502)	42	0.00
Cooling load	Baseline load	Intercept	449	1,846	95	0.00
		Treatment	449	(265)	122	0.03
	DID	Intercept	449	(3)	39	0.95
		Treatment	449	230	71	0.00

Table 6-3 provides electric NAC, heating, and cooling model results for the HVAC heat pump replacement technology group.

Table 6-3. Electric NAC, heating, and cooling savings models for HVAC heat pump replacement technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	116	8,478	494	0.00
		Treatment	116	503	705	0.48
	DID	Intercept	116	82	117	0.48
		Treatment	116	(369)	196	0.06
Heating load	Baseline load	Intercept	117	321	46	0.00
		Treatment	117	145	74	0.05
	DID	Intercept	117	(21)	40	0.60
		Treatment	117	(58)	69	0.40
Cooling load	Baseline load	Intercept	116	1,932	180	0.00
		Treatment	116	(86)	237	0.72
	DID	Intercept	116	(35)	65	0.59
		Treatment	116	54	113	0.63

Table 6-4 provides gas NAC and heating model results for the ductless HVAC fuel substitution technology group.

Table 6-4. Gas NAC and heating savings models for ductless HVAC fuel substitution technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	2,262	427	5	0.00
		Treatment	2,262	(11)	7	0.12
	DID	Intercept	2,262	29	2	0.00
		Treatment	2,262	14	3	0.00
Heating load	Baseline load	Intercept	2,259	164	3	0.00
		Treatment	2,259	(13)	4	0.00
	DID	Intercept	2,259	23	2	0.00
		Treatment	2,259	13	2	0.00

Table 6-5 provides gas NAC and heating model results for the central HVAC fuel substitution technology group.

Table 6-5. Gas NAC and heating savings models for central HVAC fuel substitution technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	472	421	13	0.00
		Treatment	472	(101)	19	0.00
	DID	Intercept	472	23	5	0.00
		Treatment	472	107	9	0.00
Heating load	Baseline load	Intercept	471	171	7	0.00
		Treatment	471	(86)	9	0.00
	DID	Intercept	471	25	4	0.00
		Treatment	471	85	7	0.00

Table 6-6 provides gas NAC and heating model results for the HVAC heat pump replacement technology group.

Table 6-6. Gas NAC and heating savings models for HVAC heat pump replacement technology

Load Component	Type	Variable	N	Estimate	Standard Error	P-value
NAC	Baseline load	Intercept	141	418	20	0.00
		Treatment	141	(51)	27	0.06
	DID	Intercept	141	37	9	0.00
		Treatment	141	61	16	0.00
Heating load	Baseline load	Intercept	143	158	11	0.00
		Treatment	143	(30)	15	0.05
	DID	Intercept	143	14	6	0.02
		Treatment	143	46	11	0.00

6.2 Appendix B: Bill impact rate schedules

Table 6-7 provides the gas rates and Table 6-8 provides the gas rate types used in the bill impact calculations. Sources for each are provided below the tables. DNV did not include fixed costs in this analysis, as most participants continued to have some gas service following the heat pump installations.

Table 6-7. Gas rates used in bill impact calculations

Rate schedule	Month	Rate type	Rate ($/therms)
Residential Gas Service, Individually Metered (GR)	1	Baseline	1.66056
		Non-Baseline	2.07446
	2	Baseline	1.43142
		Non-Baseline	1.84532
	3	Baseline	1.38408
		Non-Baseline	1.79798
	4	Baseline	1.40630
		Non-Baseline	1.82020
	5	Baseline	1.56805
		Non-Baseline	1.98195
	6	Baseline	1.85975
		Non-Baseline	2.27365
	7	Baseline	1.58482
		Non-Baseline	1.99872
	8	Baseline	1.80027
		Non-Baseline	2.21417
	9	Baseline	1.79481
		Non-Baseline	2.20871
	10	Baseline	1.47907
		Non-Baseline	1.89297
	11	Baseline	1.47446
		Non-Baseline	1.88836
	12	Baseline	1.87816
		Non-Baseline	2.29206
Residential Gas Service, Individually Metered, Transportation-Only Service Option (GT-R)	All	Baseline	0.82487
		Non-Baseline	1.23877

Source: https://www.socalgas.com/sites/default/files/RES2022.xlsx

Table 6-8. Gas rate types used in bill impact calculations

SCG Baseline Climate Zone	Time period	Daily therm allowance
1	Summer (May 1 - Oct. 31)	0.424
	Winter On-Peak (Jan., Feb., and Dec.)	1.600
	Winter Off-Peak (Mar., Apr, and Nov.	0.874
2	Summer (May 1 - Oct. 31)	0.424
	Winter On-Peak (Jan., Feb., and Dec.)	1.867
	Winter Off-Peak (Mar., Apr, and Nov.)	0.923
3	Summer (May 1 - Oct. 31)	0.424
	Winter On-Peak (Jan., Feb., and Dec.)	2.600
	Winter Off-Peak (Mar., Apr, and Nov.	1.714

Source: https://tariff.socalgas.com/regulatory/tariffs/tm2/pdf/tariffs/GAS_G-SCHEDS_GR.pdf

Table 6-9 provides the electric rates and Table 6-10 provides the rate types used in the analysis.

Table 6-9. Electric rates used in bill impact calculations

Rate schedule	Rate type	Rate ($/kWh)
Domestic (DOMESTIC)	Baseline	0.16853000
	Non-Baseline (101% - 400% of Baseline)	0.24371000
	High Usage (More than 400% of Baseline)	0.32846000
Domestic - Care (D-CARE)	Baseline	0.12100454
	Non-Baseline (101% - 400% of Baseline)	0.17498378
	High Usage (More than 400% of Baseline)	0.23583428
Domestic - FERA (D-FERA)	Baseline	0.13819460
	Non-Baseline (101% - 400% of Baseline)	0.19984220
	High Usage (More than 400% of Baseline)	0.26933720
Domestic - Employees (DE)	Baseline	0.12639750
	Non-Baseline (101% - 400% of Baseline)	0.18278250
	High Usage (More than 400% of Baseline)	0.24634500
TOU	June - September, Mid Peak (Weekdays, 4 p.m. – 9 p.m.)	0.49000000
	June - September, Mid Peak (Weekends, 4 p.m. – 9 p.m.)	0.40000000
	June - September, Off Peak (Remaining hours)	0.30000000
	October - May, Peak (4 p.m. – 9 p.m.)	0.43000000
	October - May, Super Off Peak (8 a.m. - 4 p.m.)	0.29000000
	October - May, Off Peak (Remaining hours)	0.32000000

Source: https://www.sce.com/regulatory/tariff-books/historical-rates
Source: https://www.sce.com/residential/rates/Time-Of-Use-Residential-Rate-Plans

Table 6-10. Electric rate types used in bill impact calculations

Climate Zone	Time period	kWh per day
5	Summer (June 1 - Sep. 30)	17.2
	Winter (Oct. 1 - May 31)	18.7
6	Summer (June 1 - Sep. 30)	11.4
	Winter (Oct. 1 - May 31)	11.3
8	Summer (June 1 - Sep. 30)	12.6
	Winter (Oct. 1 - May 31)	10.6
9	Summer (June 1 - Sep. 30)	16.5
	Winter (Oct. 1 - May 31)	12.3
10	Summer (June 1 - Sep. 30)	18.9
	Winter (Oct. 1 - May 31)	12.5
13	Summer (June 1 - Sep. 30)	22
	Winter (Oct. 1 - May 31)	12.6
14	Summer (June 1 - Sep. 30)	18.7
	Winter (Oct. 1 - May 31)	12
15	Summer (June 1 - Sep. 30)	46.4
	Winter (Oct. 1 - May 31)	9.9
16	Summer (June 1 - Sep. 30)	14.4
	Winter (Oct. 1 - May 31)	12.6

Source: https://www.sce.com/regulatory/tariff-books/historical-rates

6.3 Appendix C: Analysis of peak demand impacts

The evaluation team conducted an analysis of peak demand impacts based on hourly consumption data models used to determine annual kWh impacts. Table 6-11 provides the results of the peak demand analysis by technology group and climate zone and across all climate zones (shown as overall). The relative precisions and p-values for the estimates of demand impacts for the ductless HVAC fuel substitution technology in climate zone 15; the central HVAC fuel substitution technology in climate zone 8; and the heat pump replacement technology in climate zones 8, 16, and overall tell us that they are more uncertain and likely near zero.

Table 6-11. Results of the peak demand analysis by heat pump technology and climate zone

Technology	Climate zone	kW per site	Relative Precision	P-value*	% of baseline	Program total kW	Total households
Ductless HVAC fuel substitution	5	-0.14	59%	0.01	-16%	-4	27
	6	-0.07	17%	0.00	-7%	-78	1,054
	8	-0.07	21%	0.00	-5%	-81	1,126
	9	-0.03	78%	0.03	-1%	-27	954
	10	-0.15	20%	0.00	-5%	-148	1,001
	13	-0.27	35%	0.00	-6%	-30	110
	14	-0.36	10%	0.00	-15%	-211	591
	15	-0.07	92%	0.07	-2%	-41	549
	16	-0.08	65%	0.01	-4%	-10	121
	Overall	**-0.10**	**10%**	**0.00**	**-5%**	**-552**	**5,533**
Central HVAC fuel substitution	6	-0.16	25%	0.00	-14%	-28	172
	8	0.03	121%	0.18	2%	7	244
	9	-0.31	25%	0.00	-13%	-34	108
	10	0.41	23%	0.00	12%	46	111
	14	-0.60	56%	0.00	-20%	-11	19
	15	0.41	16%	0.00	11%	101	246
	16	-2.51	14%	0.00	-211%	-13	5
	Overall	**0.05**	**51%**	**0.00**	**2%**	**47**	**905**
Residential HVAC heat pump replacement	6	-0.37	24%	0.00	-29%	-12	34
	8	0.06	86%	0.06	4%	4	65
	9	-0.36	25%	0.00	-15%	-14	40
	10	0.43	26%	0.00	12%	35	81
	14	-0.31	42%	0.00	-11%	-15	48
	15	0.36	48%	0.00	9%	17	47
	16	0.17	108%	0.14	6%	2	10
	Overall	**0.00**	**1296%**	**0.90**	**0%**	**-1**	**325**

* P-values indicate how certain DNV is that the estimated changes in energy consumption are statistically different from 0 while the relative precisions indicate how certain the estimated changes are. For this evaluation, p-values that are less than or equal to 0.1 are considered good.

Figure 6-1 below illustrates the kW peak demand savings per site by HVAC heat pump technology and climate zone, as well as across all climate zones. For the ductless HVAC fuel substitution technology, peak demand savings was near zero or negative at the climate zone level, with a per site impact result across all climate zones of -0.10 kW. For the central HVAC fuel substitution technology, the per site impact across all climate zones is 0.05 kW, with substantial demand savings per site for installations in climate zones 10 and 15. For the heat pump replacement technology, the per site impact across all climate zones is near zero. However, there were substantial demand savings per site for heat pump replacements in climate zones 10 and 15.

Figure 6-1. Peak demand savings per site by climate zone and overall

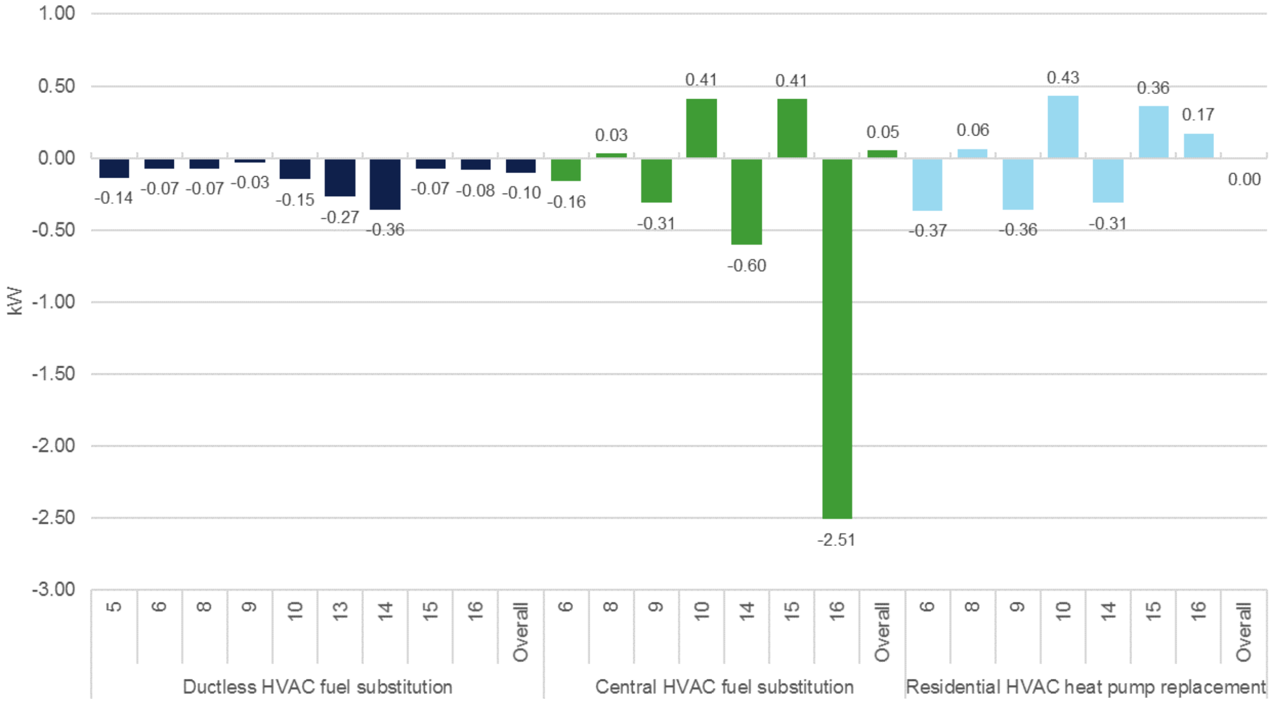
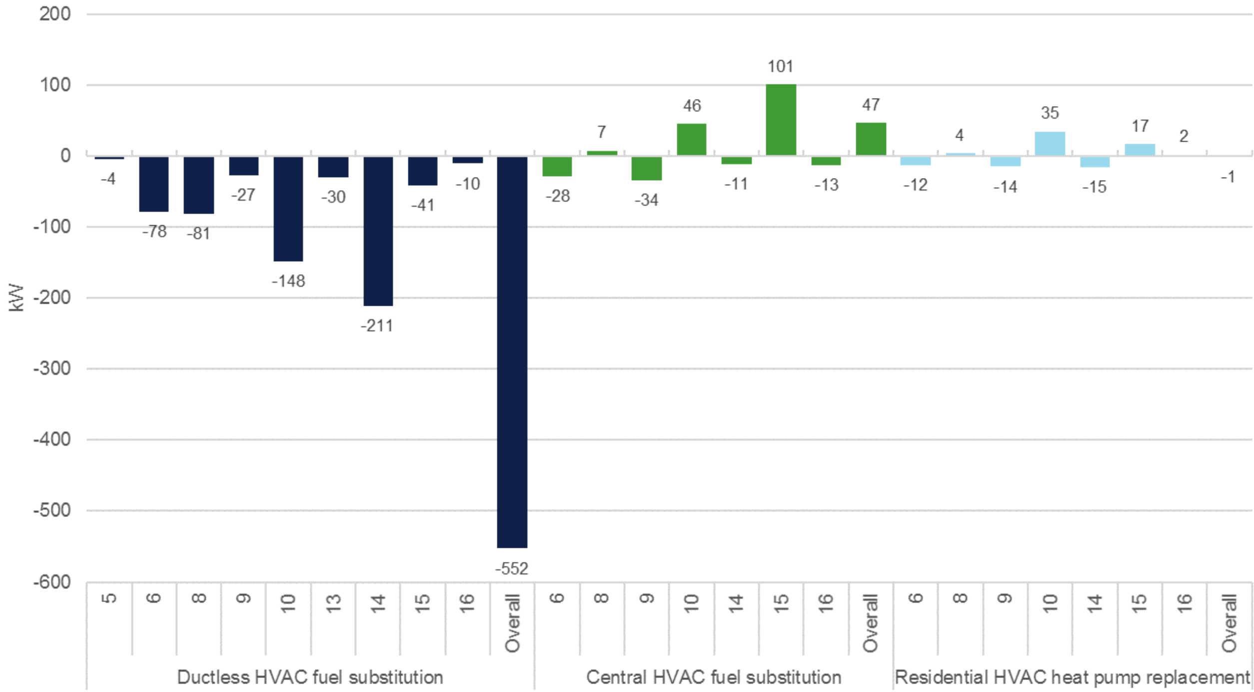


Figure 6-2 below presents the program's total peak demand savings by climate zone and across all climate zones for each heat pump technology. These results represent the product of the per site demand impacts and the program populations in each climate zone and so are weighted by the proportion of claims in a respective climate zone. For program total demand impacts, overall, the ductless HVAC fuel substitution technology is a larger increase in peak demand (-552 kW) than the central HVAC fuel substitution technology is a decrease in peak demand load (47 kW). The heat pump replacement technology peak demand impact is near zero and statistically insignificant.

Figure 6-2. Program total peak demand savings by climate zone and overall



6.4 Appendix D: Standardized High-Level Savings

2023.04.05_SW3P_P
LA_IESR_APPENDIX_[

6.5 Appendix E: Standardized Per-Unit Savings

2023.04.05_SW3P_P
LA_IESR_APPENDIX_E

6.6 Appendix F: Stakeholder comments and evaluator responses

Table 6-12. Stakeholder comments on the study and evaluator response

#:	Subject:	Entity:	QUESTION or COMMENT:	Evaluator Response:
1	Explanation of therm impacts GRR	SCG	The report explained about 56% of total claims for kWh and no mention on therms?	The 56% of the reported program attributable (net) lifecycle electric energy (kWh) savings comprises of combined (gas and electric) impacts shown in kWh units.
2	Explanation of therms impacts relative to electric impacts for ductless HVAC fuel substitution measures	SCG	What explains low gross gas savings (6%) but relatively high percent of electric increase (85%) for ductless HVAC fuel substitution measure?	The majority of participants who installed the ductless HVAC fuel substitution measure are not significantly offsetting pre-retrofit gas heating. Additionally, there's added year-round electric load. This is in part because, as survey respondents indicate, the ductless HVAC fuel substitution measure is not often replacing an existing gas system.
3	Explanation of lower therm impacts for central HVAC fuel substitution measure relative to PY2020 findings	SCG	What explains decrease to 54% gross gas savings for central HVAC fuel substitution measure?	PY2021 participants with the central HVAC fuel substitution measure have lower gas baseline consumption and lower gas heating baseline consumption relative to the PY2020 participants. The lower the gas baseline consumption, the less opportunity for gas savings.
4	Future of DHW and HVAC fuel substitution measures after PLA program sunset	SCG	Upstream (HPWH – DHW), Midstream – ductless and central (98% of claims). No PLA in PY2022 – are these measures going to be sunset?	While SCE's PLA program transitioned to state-wide administered program after PY2021, the measure packages continue to be available for program administrators to claim, although the midstream delivery channel for the ductless HVAC fuel substitution measures will cease to be available starting in PY2024.

#:	Subject:	Entity:	QUESTION or COMMENT:	Evaluator Response:
5	Explain types of systems being replaced to help target or redirect the measure.	SCG	For central HVAC fuel substitution, can the number of participants that have different types of systems being replaced be segmented? This would help target or redirect the measure by knowing what is actually happening (not just that gas savings that didn't materialize or there is a bigger electric increase than expected).	The information on the different replaced HVAC types comes from survey responses. The number of survey respondents that would allow segmentation by replaced systems is limited and does not make it possible to obtain robust estimates that can be the basis for reliable decision-making.
6	Explain future evaluations and possibility of reclassing to Central HVAC substitution measure.	SCG	For HVAC replacement, gas savings result where none are expected. Did the evaluation consider for this or future evaluations reclassifying those projects to the central HVAC substitution measure?	Although the analysis suggests to the evaluator that some portion of these claims could represent fuel substitution, it is not the proper function or role of the evaluator to reassign measure designation claims made in the tracking data by the program administrator.
7	Explanation to for more participation data collection	SCG	Given the positive bill advantages and the diverse and CARE participation, recommend continue offering / restructuring the ductless measure somehow, maybe even as a downstream measure to allow better participant data collection?	The ductless HVAC fuel substitution technology group shows modest average annual bill savings for participants, with higher savings for those enrolled in CARE or FERA. Additionally, the diverse income range and CARE participation suggest that the program is reaching a broad audience. Evaluators concur that enhancing the rigor of participant data collection for downstream processes will result in improved data quality. DEER resolution for PY2024 enables program administrators to reach hard to reach customers. The delivery type will be restricted to downstream to adhere for better data collection.
8	Add downstream recommendation	SCG	For ductless recommendation, include possible downstream here, same for HPWHs for DHW	The downstream program design will take effect PY2024, per the DEER resolution for both HPWH and heat pumps.

#:	Subject:	Entity:	QUESTION or COMMENT:	Evaluator Response:
9	Explanation in more detail custom info for midstream.	SCG	Can the evaluators explain in more detail how the distributors provided customer info for the midstream program?	Distributors provided measure details, installation address, customer contact information, contractor contact information, incentive amount, and the claim ID associated with the measure for each HVAC heat pump installation. The evaluation team leveraged these data to deploy surveys and identify participant SCE and SCG accounts for the gross savings analysis. DNV requested and received the distributor data from SCE.
10	More detail on how NAC was conducted.	SCG	As far as NAC, how was this conducted? Was there more than 10% saving based on IPMVP option C analysis?	NAC is weather-normalized annual electricity and gas consumption obtained using the widely applied PRISM approach. Under this approach, we run site-level regressions to model energy consumption as a function of weather and use model results to determine annual energy use based on typical or normal weather. Such weather normalization removes the impact of weather fluctuations on energy use. NAC values from participants and matched non-participants are then used in a difference-in-difference (DID) model to determine the impact of program installations. DID modelling controls for the effect of non-program changes on energy use. This two-stage consumption data analysis framework, with weather normalization in the first stage and DID in the second stage, is consistent with the approach laid out in the Uniform Methods Project (UMP) Chapter 8, which provides whole-house savings estimation protocols for energy efficiency interventions that have whole-home impacts. It is relevant in the current context where the program installs electrification measures that provide whole-home savings. The approach is also consistent with the IPMVP option C

#:	Subject:	Entity:	QUESTION or COMMENT:	Evaluator Response:
				analysis at the individual whole-home level. Additional detail can be found in Appendix A: Consumption data analysis of the report.Overall, the approach generated gas savings of about 8% for customers with a heat pump installation and above 10% for customers who replaced their HVAC systems with heat pumps. Customers with the central HVAC fuel substitution measure had gas savings of 25%, customers with the ductless HVAC fuel substitution measure had gas savings of 3%, and customers with the residential HVAC heat pump replacement measure had gas savings of 15%. Of the customers with the ductless HVAC fuel substitution measure, those that reported replacing their existing HVAC system with the heat pumps had gas savings of 11%.
11	Explain if gas substitution occurred and if other program rules could produce projected results	SCG	Lower numbers for central and ductless for res indicates that gas substitution may not always be occurring. Any attempt to quantify (or can you quantify) if gas substitution occurs, are the measures more effective? For example, could more stringent program rules help achieve intended results?	Combining the consumption analysis and the survey results indicates that on average, when the ductless HVAC system does replace an existing heating system, the annual gas savings are 3 times greater than the overall ductless HVAC fuel substitution group. Despite annual gas savings that are 3 times greater than the overall ductless HVAC fuel substitution technology group, these annual gas consumption savings are still only about 20% of the reported savings. This suggests that more stringent program rules could help increase gas savings, but this doesn't account for all the unachieved gas savings. See Table 4-2 for impacts of ductless replacing existing systems.

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12	Provide more detail on customer electric and gas accounts	SCG	Are all customers matched for electric and gas accounts?	Yes, DNV matched the addresses of participants with both SCE electric and SCG gas accounts. The matching used addresses to identify premise IDs and names to help identify the customer IDs. The "Account Identification Table" in the report provides the customer and premise IDs of the matched participants using both IOUs' CIS files. The report also provides additional details on how DNV conducted these matches. See Section 3.1.2, Sampling and 3.1.3, Participant Account Identification.
13	Provide more detail on control group	SCG	Please discuss the control group more, verifying for instance that they are not performing the same or other EE measures, relevant changes in characteristics, etc. Possibly NA if group is large. What size is the group?	DNV selected potential comparison group households after removing all IOU customers who participated in any utility EE programs in PY2020 and PY2021. The exclusion ensures that both the pre-and post-periods in the analysis do not include customers that may have received interventions through other programs. We then matched participants with the customers that did not participate in any EE programs in the two program years. The selected non-participants were those whose energy load profile (annual and seasonal energy use) resembled those of participants closely. The number of matched non-participants, which was the same as the number of participants, was sufficiently large to provide robust (statistically significant and precise) savings estimates.
14	Explain NTGR results and add to Appendix	SCG	NTGR research not conducted for 2021. 2020 results should be discussed briefly here and, in the Appendix, as well.	Section 4.1.3 Program Attribution added to the report which summarize program attribution findings from PY2020's report. A reference to Appendix F within PY2020 report has been added to the report, which explains the NTGR methodology.

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15	Gas consumption savings explanation	SCG	Please expand on this: 'For the central HVAC fuel substitution heat pump installations, the similarity between the gross realization rate of reported electric consumption increases and the gross realization rate of gas consumption savings suggests that a component in the savings calculation is systematically overstated'. What is the gap in the savings analysis, and what is overstated?	The results suggest there may be a misalignment with the measure packaged used and the actual measure installed and replaced. The measure package in the TRM assumes fuel substitution is always taking place. Possible overstated components of the calculation may be leading to overstated baseline consumption. However, the evaluators cannot determine with certainty which component is overstated from the current research and recommend further investigation into the savings algorithm for appropriateness.
16	Study objectives and future research	SCE	Since the upstream component has a cost reduction objective, it would be helpful to have an assessment of cost trends associated with program activity. Similarly, it would be helpful to have research to determine program impacts on manufacturer promotion such as shelf studies perhaps in PY 2023/2024. Such a research program could track gas system decline which may increase gas savings as units fall out of service. In theory, this research could support the targeting of households to maximize program savings and GHG reductions.	The opinion of the evaluators is that program administrators are better suited to conduct the proposed program cost and marketing study due to their connections to implementers and market actors through the program.
17	Recommended future research	SCE	SCE recommends research with mini-split participants to assess changes in program participant's use of their mini-splits for heating vs. existing furnaces that were left in place. This study could inform lifecycle savings analysis that currently assumes participants will continue to use their natural	The evaluators encourage the commenter pursue their proposal for a prospective longitudinal study to determine the persistence of measure impacts.

#:	Subject:	Entity:	QUESTION or COMMENT:	Evaluator Response:
			gas heaters over the EUL of the newly installed mini-splits	
18	Ductless HVAC measure potential for home additions & a code minimum efficient measure	SCE	SCE sees potential in a mini-split measure for home-expansion that avoids a natural gas wall furnace installation (i.e., a home-expansion customer doesn't need to install a wall furnace then rip it out in order to be eligible for a mini-split fuel substitution incentive). In addition, the approval of code minimum fuel substitution measures is one way to significantly improve the impact of fuel substitution measures through improved TRC potential, increased equitable participation for lower income customers, increased avoided GHG emissions, and accelerated market adoption. The addition of this measure would significantly increase the participation potential for central HVAC heat pumps that dominate the single-family home market.	The new construction application type proposed by the commenter is afforded by fuel substitution technical guidance and expressly called out in the previous (-01) and current measure packages (-02) via downstream delivery designs. Incentivizing code-minimum equipment is not permitted under the CPUCs policies on energy efficiency.

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19	Previous evaluation recommendation	SCE	SCE noted in our PY2020 comments and the recent PY2021 Webinar is our belief that HVAC midstream/upstream programs are critical for supporting decarbonization goals. Rather than restricting these delivery channels in future programs (PY2024), we need to collaborate on solutions and “program controls” (including data collection processes) to preserve these programs while improving realization rates.	The PY2020 and PY2021 evaluation of SCE's PLA program ductless HVAC fuel substitution claims demonstrated there is a significant risk of programs not ensuring their participants meet measures requirements or meet the expected benefits of this effort to decarbonization when PAs administer this measure package via the midstream channel. The evaluators recommendation remains to focus future efforts on downstream delivery channels for this measure to ensure measure requirements are met and to provide the highest assurance that the measures are executed to their highest potential.
20	Sample size and method for reporting ductless HVAC participants characterizing the application of their systems	SCE	Is there a count available of installations that did and did not replace existing systems? Was this determination made by survey response or another method?	The survey asked participants about why they installed the new heating and cooling system. For participants with a ductless HVAC measure (n=380), when asked about their heating system: 151 reported replacing an existing system, 120 reported adding to the existing system, 80 reported some other response, and 29 did not know or did not respond. When asked about their cooling system: 93 reported replacing an existing system, 243 reported adding to the existing system, and 44 did not respond. See report section 4.7 System attributes and participant experience.

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