EM&V GROUP A - FINAL IMPACT EVALUATION REPORT

# Residential Direct Install Program Impact Evaluation - Program Year 2021

California Public Utilities Commission
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DNV

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# 1 EXECUTIVE SUMMARY

This report presents DNV's evaluation of residential direct install[1] programs offered in program year (PY) 2021. The programs, offered by Southern California Edison (SCE) in PY2021, included Residential Direct Install (SCE-13-SW001)[2] and Comprehensive Manufactured Homes (SCE-13-TP-001)[3] programs. These programs, collectively referred to as Res DI, are part of the traditional energy efficiency (EE) programs designed and led by the program administrators (PAs). DNV conducted this evaluation on behalf of the California Public Utilities Commission (CPUC) and evaluated these programs due to their energy savings contribution to the EE portfolio. The programs also contributed a substantial portion of the PY2021 claimed kilowatt (kW) reduction from all deemed[4] EE and residential programs.

This is our third evaluation of residential direct install programs run by California PAs. Unlike the prior program years, only Southern California Edison (SCE) ran two residential direct install programs in PY2021, which targeted low to moderate-income customers and primarily offered technologies to save heating, ventilation, and air conditioning (HVAC) energy use.

We used utility-provided energy consumption and customer information, survey, and publicly available data to determine program savings and delivery performance.

Our findings indicate that the programs delivered a small fraction of their claimed savings but were responsible for influencing significant portions of the evaluated or achieved savings, indicating that the programs reached population segments that benefited from the programs' EE services. The programs also contributed to peak demand reductions, including during summer peak hours.

The single-family Residential Direct Install Program rolled out integrated demand side management (IDSM) for the first time in PY2021 by enrolling qualifying customers that received smart thermostats in the SCE's demand response (DR) program. This effort was largely successful because over three-fourths of those that recalled receiving information about the DR program reported that they enrolled in the program.

Moreover, participants reported being generally satisfied with the programs and wanted more information to achieve greater savings and additional benefits from the installations they received. The programs successfully served a high proportion of customers in disadvantaged communities (DACs) [5] and outside of metro areas.[6] Disadvantaged communities refer to the areas throughout California that most suffer from a combination of economic, health, and environmental burdens. The programs also deployed their offerings in hot climate zones where they are likely to be more effective.

## 1.1 Study background

The Res DI programs delivered the EE measures[7] and services to low and moderate-income single-family and manufactured/mobile home customers ineligible for low-income assistance programs. Based on CPUC Decision 21-06-015,[8]

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1 Direct install programs provide energy saving technologies or upgrades for no or low-cost in participating customer homes through installation contractors.

2 This program serves residents of single-family homes. Southern California Edison, "Residential Direct Install Program," https://www.sce.com/residential/rebates-incentives-saving-tips/residential-direct-install-program

3 This program serves residents of manufactured/mobile homes. Southern California Edison, "Manufactured Home Program," https://www.sce.com/residential/rebates-savings/manufactured-home-program

4 Deemed programs provide EE technologies and services with well-established properties, including predefined savings and other attributes. By contrast, custom programs offer EE technologies and services that require unique calculations and do not use predefined values.

5 CPUC, "Disadvantaged Communities," cpuc.gov, 2021, https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/disadvantaged-communities

6 Non-metro refers to regions outside the U.S. Office Management and Budget core statistical (CBSAs) areas of the San Francisco Bay area, San Diego, Greater Los Angeles (Los Angeles, Orange, San Bernardino, Riverside, and Ventura counties), and Sacramento.

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

8 "Southern California Edison's Implementation Plan Comprehensive Manufactured Homes," cedars.sound-data.com, 12/23/2021, SCE EE Program Implementation Plan Template V2.0 (sound-data.com).

the programs targeted customers that are hard-to-reach (HTR)[9] and are in DACs, rural and tribal areas, public safety power shut off (PSPS) and wildfire zones, and emergency load reduction program hot climate zones (9, 10, 13, 14, and 15).

In PY2021, the Res DI programs offered no-cost direct installations from the same suite of EE measures and services. These comprised of site-appropriate packages that included smart thermostats, duct test and sealing, brushless fan motor replacement, fan delay motor controllers, condenser coil cleaning, faucet aerators, and showerheads.

Additionally, Residential Direct Install initiated an integrated demand side management (IDSM) effort in PY2021 by enrolling qualified customers that installed smart thermostats into SCE's Demand Response Smart Energy Program. This is in line with CPUC Decision 07-10-032 directing utilities to offer IDSM that simplifies customer energy management decisions and allows customers to be more load responsive.[10]

## 1.2 Research objectives

The research objectives for the PY2021 Res DI program evaluation include:

- Estimate gross[11] energy savings of the Res DI programs.
- Estimate the portions of the savings attributable to the programs.
- Determine the hourly savings shape of participants in the programs.
- Estimate the peak demand savings provided by the programs.
- Understand participant characteristics and program benefits.

## 1.3 Study approach

**Gross savings.** DNV used consumption data analysis to estimate whole-home energy savings of the Res DI programs. Since Res DI delivered multiple measures, DNV allocated whole-home savings to the multiple installed measures using engineering estimates. We also used separate consumption data analysis for direct install homes that received single measures to confirm the allocation of the whole home savings.

Since SCE does not have gas consumption data, we estimated the programs' PY2021 whole-home, smart thermostat, and duct test and sealing gas savings claims based on PY2020 savings estimates of the measures for each dwelling type and climate zone.

We also estimated the Res DI programs' hourly savings shapes and peak demand impact using Advance Metering Infrastructure (AMI) data-based hourly kW impact models. We provide such estimates at the program level and for homes that received single measures.

**Program influence.** We conducted web surveys with residential participants and selected non-participants. Sample sizes are shown in Table 1-1. We used the information gathered to determine the influence of the programs on participation and the amount of savings that can be attributed to the programs (net savings). We estimated net savings using net-to-gross ratios (NTGRs).[12] NTGR estimates based on the sample sizes shown below satisfy the 90/10 minimum confidence level and precision requirements.

[9] Hard to reach (HTR): 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

[10] "Interim Opinion on Issues Relating to Future Savings Goals and Program Planning for 2009-2011 Energy Efficiency and Beyond 11", docs.cpuc.ca.gov, 10/18/2007 https://docs.cpuc.ca.gov/published/FINAL_DECISION/74107.htm

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

[12] Net to Gross ratios ((NTGR) are used to estimate and describe the "free ridership" that may be occurring within energy efficiency programs, that is, the degree to which customers would have installed the program technology or equipment without the program benefits participate in the programs. Gross savings are multiplied by the NTGR to arrive at net savings.

Table 1-1. Survey efforts and sample size summary

| Surveys | Mode | Population targeted | Completed surveys | Response rates |
|---|---|---|---|---|
| Residential participant survey | Web | 9,381 | 994 | 10.6% |
| Residential non-participant survey | Web | 72,549 | 3,739 | 5.2% |

**Program performance and participation characterization.** For PY2021, we broadened our evaluation effort to understand program benefits and characterize program participation. To understand the benefits of the Res DI programs, beyond the energy savings they delivered, we examined three dimensions of program delivery and composition. First, we examined the performance of the Res DI programs' PY2021 innovation (IDSM) based on data collected from surveys. Second, we also used survey data to assess customer experience and program satisfaction. Finally, we integrated additional data to examine program participant characteristics.

The additional data included program implementation plans (PIPs), implementer interviews, utility customer information system (CIS) data, and the American Community Survey (ACS) data. Using these data, we examined the percentage of participants that resided in areas targeted by the programs, including non-metro areas, hot climate zones, and DACs. We also used these data to assess the percentage of HTR customers, renters, and those on California Alternative Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs.[13]

**Equitable evaluation.** This is the first year where evaluations focused on program outcomes. This created an opportunity to conduct a "process" evaluation of the programs in relation to the CPUC's *Environmental and Social Justice Action Plan (ESJ Plan) goals.*[14] Although these goals were not established until 2021, after the evaluated programs were designed, this evaluation provides a baseline which future program implementation can seek to exceed and a foundation for recommendations that will help the programs do so. DNV's equitable evaluation framework tracks the principles and relevant CPUC ESJ goals: 1, 2, 3, 4.1, 5, 6.1, 8, and 9.

## 1.4 Key findings

### 1.4.1 Gross and net impacts

Table 1-2 provides the number of electric savings claims associated with measures installed through Res DI programs, the claimed electric savings (total gross claimed savings), and the achieved savings (total gross evaluated savings). The measures installed by the programs achieved approximately 876 MWh of gross electric savings, which is 10% of gross claimed savings (gross realization rate). Total evaluated gross savings are further adjusted to reflect the portion of savings that are due to program influence using net-to-gross ratios (NTGR). Our evaluation indicates that the Res DI programs caused electric savings of 721 MWh.

Table 1-2. Total residential HVAC electric savings

| Measure | Number of installations | Total Gross savings (kWh) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total Net Evaluated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Smart thermostats | 12,597 | 2,958,751 | 406,167 | 14% | 90% | 83% | 337,119 |
| Fan motor replacement | 2,099 | 888,857 | 135,245 | 15% | 64% | 85% | 114,958 |
| Fan motor controls | 5,861 | 1,987,221 | 224,584 | 11% | 69% | 76% | 170,684 |
| Duct test and seal | 514 | 100,356 | 48,133 | 48% | 57% | 87% | 41,876 |

[13] California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs provide energy bill discounts for income qualified households in California. CARE is a proxy for low-income and is one of the criteria used to define HTR.

[14] California Public Utilities Commission, "Environmental & Social Justice Action Plan," cpuc.ca.gov, April 7, 2022 https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/news-and-outreach/documents/news-office/key-issues/esj/esj-action-plan-v2jw.pdf

| Measure | Number of installations | Total Gross savings (kWh) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total Net Evaluated Savings (kWh) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Coil cleaning | 139 | 6,514 | 2,798 | 43% | 58% | 91% | 2,546 |
| Fan repair | 153 | 2,060 | 901 | 44% | 58% | 91% | 820 |
| Refrigerant charge adjustment (RCA) | 3,901 | 2,472,135 | 51,489 | 2% | 64% | 91% | 46,855 |
| Water heating (aerators) | 2,356 | 220,445 | 6,969 | 3% | 66% | 81% | 5,680 |
| **Total** | **27,620** | **8,636,339** | **876,287** | **10%** | **74%** | **82%** | **720,537** |

Table 1-3 summarizes the gas savings of the measures installed by the Res DI programs. These measures achieved 75,316 therms of gross gas savings, which is 48% of claimed gross gas savings. The programs influenced 83% of the achieved savings and caused gas savings of 62,853 therms.

**Table 1-3. Total residential HVAC gas savings**

| Measure | Number of installations | Total Gross Savings (therms) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total Net Evaluated Savings (therms) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Smart thermostats | 12,587 | 163,734 | 72,222 | 44% | 90% | 83% | 59,944 |
| Fan motor replacement | 2,099 | -10,655 | 0 | 0% | 70% | 86% | 0 |
| Duct test and sealing | 514 | 5,377 | 3,095 | 58% | 56% | 94% | 2,909 |
| Coil cleaning | 139 | -4 | 0 | 0% | 62% | 94% | 0 |
| Fan repair | 153 | -1 | 0 | 0% | 63% | 91% | 0 |
| Refrigerant charge adjustment (RCA) | 3,901 | -786 | 0 | 0% | 71% | 94% | 0 |
| **Total** | **19,393** | **157,665** | **75,316** | **48%** | **89%** | **83%** | **62,853** |

Figure 1-1 provides claimed and evaluated measure-level savings per household for all direct install program measures for PY2019 through PY2021. The claimed savings (left three columns for each measure) and evaluated savings (right three columns for each measure) are of similar magnitude across the three program years and the evaluated savings are lower than claimed in all years. The four measures evaluated in PY2021 (fan repair, coil cleaning, RCA, and water heating measures) but not in the prior program years are not included in the figure. This figure suggests that deemed savings estimates for smart thermostats, fan motor replacements, and fan motor controls require revision.

**Figure 1-1. Comparison of PY2019 through PY2021 electric claimed and evaluated measure savings per household**

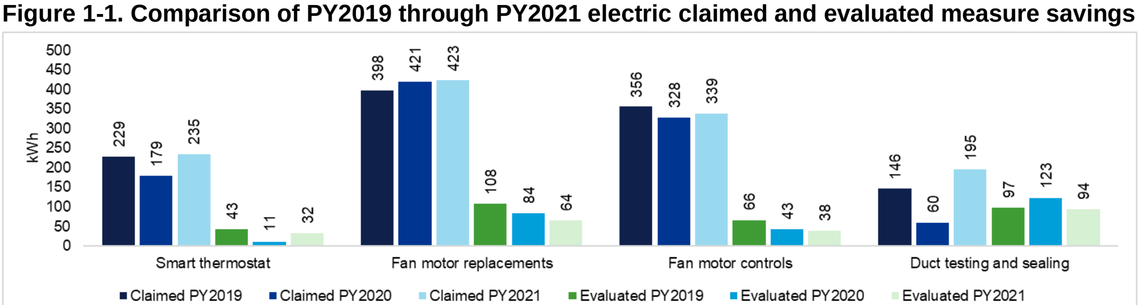
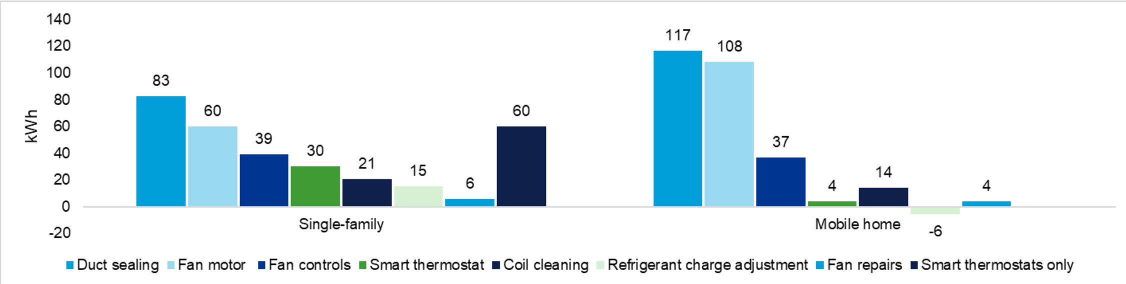



Figure 1-2 provides the PY2021 average measure savings by dwelling type. It also provides smart thermostat savings for single-family homes that received this measure alone and had sufficient data available for the evaluation. As the figure indicates, fan motors and duct test and sealing delivered the highest savings in both dwelling types in PY2021. Smart thermostats installed alone also had higher savings than those installed as part of a bundle in single-family households.

**Figure 1-2. Measure-level electric savings, PY2021 Res DI programs**




As indicated above, the current evaluated savings per measure are similar to those found in the previous direct install program evaluations for PY2019 and PY2020. Those evaluations also found low realization rates, that is, claimed savings per unit were higher than the evaluated savings. While some changes were adopted to claims calculations and to program offerings based on those earlier findings, those changes were not yet in place for PY2021. Specific contributors to the low GRR in PY2021 include:

- The RCA measure, which accounted for 29% of claimed PY2021 savings, had savings that were considerably lower than claimed in PY2021. This measure has since been retired.[15]
- Smart thermostats are a largely behavioral measure. Among the installed measures, they have the unique potential to have low or even negative savings depending on how they are used. In the current evaluation, mobile homes without smart thermostats in their measure bundle had a whole-home savings of 213 kWh (a gross realization rate of approximately 46%) while those whose installation included a thermostat among their measure bundle had savings of 34 kWh (a gross realization rate of only 6%).[16]
- Fan motor replacements and fan controls, which also account for a substantial portion of PY2021 claimed savings, had evaluated savings lower than claimed.

### 1.4.2 Savings shape and peak demand reduction

To understand when the installed measures deliver electric savings, DNV conducted a savings shape analysis, which provides average electric savings during each hour of the day. Figure 1-3 provides the savings shapes for homes that installed measures other than smart thermostats, consisting of HVAC measures, including fan motor replacements and duct sealing. The figure indicates that these measures deliver most of their summer savings during afternoon hours, which include the peak demand period of 4 p.m. to 9 p.m. The savings during these hours demonstrate the measures' potential to reduce demand during summer periods when there's more stress on the grid due to high energy use. These measures make the HVAC system more efficient by producing energy savings and demand reduction across all cooling hours regardless of whether occupants were home or not. The measures deliver most of their winter savings during the early morning hours and, to some extent, in the late afternoon hours.

[15] The CPUC removed the RCA measure in Resolution E-5152 from approved deemed measures effective January 2023 because of refrigerant leakage concerns and its consistently lower evaluated savings than claimed. https://cedars.sound-data.com/deer-resources/deer-versions/2023/file/11/download.

[16] The CPUC lowered smart thermostat savings in Resolution E-5221 by approximately 10% effective January 2024 based on the PY2020 evaluation. https://cedars.sound-data.com/deer-resources/deer-versions/2024/file/2963/download

**Figure 1-3. Res DI average hourly savings for homes without smart thermostat installations**


Figure 1-4 provides savings shapes for homes that only installed smart thermostats. This figure indicates that the measure delivered most of its savings during the early afternoon hours of the summer. Savings are highest when most people are likely out of the home, and the technology can adjust the thermostat's setpoints to reduce electricity consumption. DNV identified a similar savings shape in its PY2019 evaluation. Our PY2020 evaluation, on the other hand, indicated the absence of such savings during the afternoon hours, most probably because most participants were home due to the COVID pandemic. During the summer of 2020, the optimization feature of the thermostat may have had fewer opportunities for savings through summer setbacks.

**Figure 1-4. Res DI average hourly savings for homes with only smart thermostat installations**

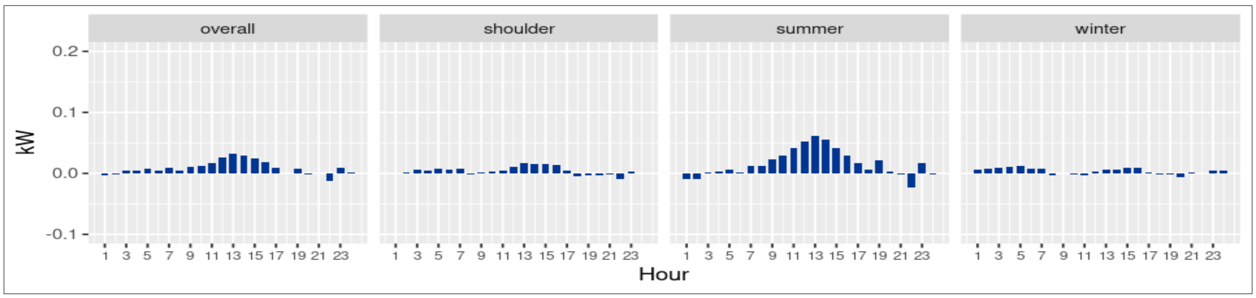



Figure 1-5 shows the hourly savings for homes that only received duct testing and sealing services. Similar to HVAC measures shown in Figure 1-3, savings for homes with this upgrade primarily occurred across all hours with HVAC load, with the highest savings taking place during the late afternoon hours. While these savings shapes are based on data from 45 homes that received only this service, they provide directional evidence of the notable contributions to peak demand reductions that this measure can offer.

**Figure 1-5. Res DI average hourly savings for homes with only duct testing and sealing**

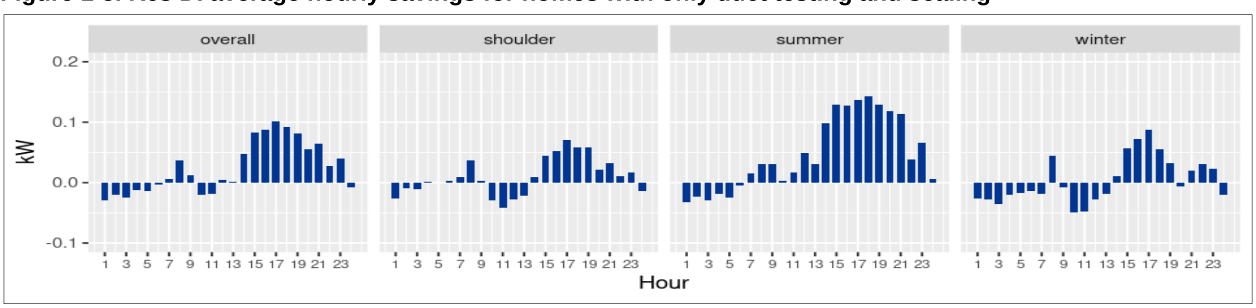


Table 1-4 summarizes the average hourly load reduction during the Database for Energy Efficient Resources (DEER)[17] peak period that covers the hours of 4 p.m. to 9 p.m. on the most extreme three days during the summer. The table summarizes results from whole-home load reduction across all participants and by certain installation activities.[18] Overall, participants saved 0.02 kW during the peak period, resulting in a 0.5% reduction in peak load. Participants who only installed smart thermostats saved about 0.2% of peak load, while participants who received measures other than smart thermostats saved 1.5% of peak load. The 45 homes that only received duct testing and sealing services reduced about 8% of their peak load.

**Table 1-4. DEER peak period average hourly baseline and load reductions for Res DI**

| Participation Segment | 4 p.m. – 9 p.m. | | | |
|---|---|---|---|---|
| | Household counts | Savings (kW) | Baseline (kW) | Percent savings |
| Overall | 7,543 | 0.02 | 3.1 | 0.5% |
| Smart thermostat only | 2,635 | 0.01 | 3.2 | 0.2% |
| No smart thermostat | 1,340 | 0.04 | 2.9 | 1.5% |
| Duct testing and sealing only | 45 | 0.22 | 2.9 | 7.6% |

## 1.4.3 Program benefits and participant characteristics

### 1.4.3.1 Program benefits

**Program delivery – IDSM.** One of SCE's objectives is to build a virtual powerplant[19] using demand response as the resource. In March of 2021, the Residential Direct Install Program initiated integrated demand side management by leveraging one of SCE's Demand Response programs called the Smart Energy Program to contribute to this objective.[20] The Residential Direct Install program educated participants who received smart thermostats from the energy-efficiency program about the benefits of demand response and enrolled qualifying customers. To gauge the success of the program's IDSM efforts, DNV asked participants that installed smart thermostats if they received an offer to enroll in SCE's Smart Energy Program. We also asked non-participants if they were aware of the same program.

Table 1-5 provides the results of the survey. Over half of the participants recalled the offer to enroll (52%), and only 17% of non-participants reported being aware of the Smart Energy Program. While awareness of the demand response program still has growth opportunities, the survey results indicated the education effort of the Residential Direct Install program is yielding success. Awareness is much higher among participants than in the general public.

Among those who recalled the program, enrollment was high at 75% for participants and relatively low at 37% among non-participants. Participants are most likely to not enroll in SCE's smart thermostat demand response program due to perceived discomfort from higher thermostat setpoints and warmer homes (even though the demand response program allows customers to override the setpoint adjustments). By contrast, non-participants provided a lack of knowledge as the primary reason for not enrolling in the program, underscoring the importance of education in increasing participation in the program.

**Table 1-5. Customer interest and willingness to enroll in SCE Smart Energy Program**

| Demand Response | Participants (a) | Non-Participants (b) |
|---|---|---|
| **Awareness** | **(n=1,089)** | **(n=3,483)** |
| **Aware/offered to enroll in SCE Smart Energy Program** | 52% | 17% |

[17] The California Database for Energy Efficiency Resources (DEER), available at eTRM: https://www.caetrm.com/, provides predefined (deemed) savings estimates and other attributes for energy efficiency measures.

[18] Whole-home reduction refers to estimates of average savings per home from the installation of all measures. This is in contrast to measure-level savings (which reflect the disaggregation of whole-home savings into individual measures savings) or savings estimates among a subset of participating homes.

[19] A virtual power plant is a system of decentralized power sources, including demand response, which can be aggregated to meet energy demand and avoid the need for expensive grid infrastructure and power-generating plants.

[20] Southern California Edison, "Demand Response Programs for Homes," https://www.sce.com/residential/demand-response https://www.sce.com/residential/demand-response

| Demand Response | Participants (a) | Non-Participants (b) |
|---|---|---|
| Enrolled | (n=565) | (n=580) |
| Enrolled in the SCE Smart Energy Program | 75% | 37% |
| Reasons for Not Enrolling | (n=49) | (n=182) |
| Do not want to compromise home comfort | 34% | 13% |
| Privacy or security concerns | 13% | 6% |
| Don't know enough about it | 7% | 34% |
| Insufficient incentives | 5% | 19% |

Choices selected by less than 10% of respondents not included in the table

**Program delivery – customer experience**. A central objective of the PY2021 evaluation is to gauge participant experience. To accomplish this, DNV surveyed customers to measure overall program satisfaction and satisfaction with the installation contractor, equipment, and information provided by the program. We also sought to understand customers' perceptions of the energy savings and non-energy benefits (noise reduction, air quality improvement, safety, and comfort) from the programs.

The survey results, presented in Table 1-6, revealed that 87% of participants have an overall favorable opinion of the programs, 85% were satisfied with the installation contractor, and 84% with the upgrades they received. These results indicate that the technology offerings and processes used to offer them are working well. Where the programs received lower satisfaction results and could improve is with customer education. Seventy-four percent of customers expressed satisfaction with the information provided by the programs. Similar percentages of customers were satisfied with energy and non-energy benefits. The programs may need to follow up to ensure installed equipment is working as intended and can provide savings and non-energy benefits. The programs may also need to provide better education and information to enable customers to receive the full benefits of the installations.

**Table 1-6. Participant experience and benefits**

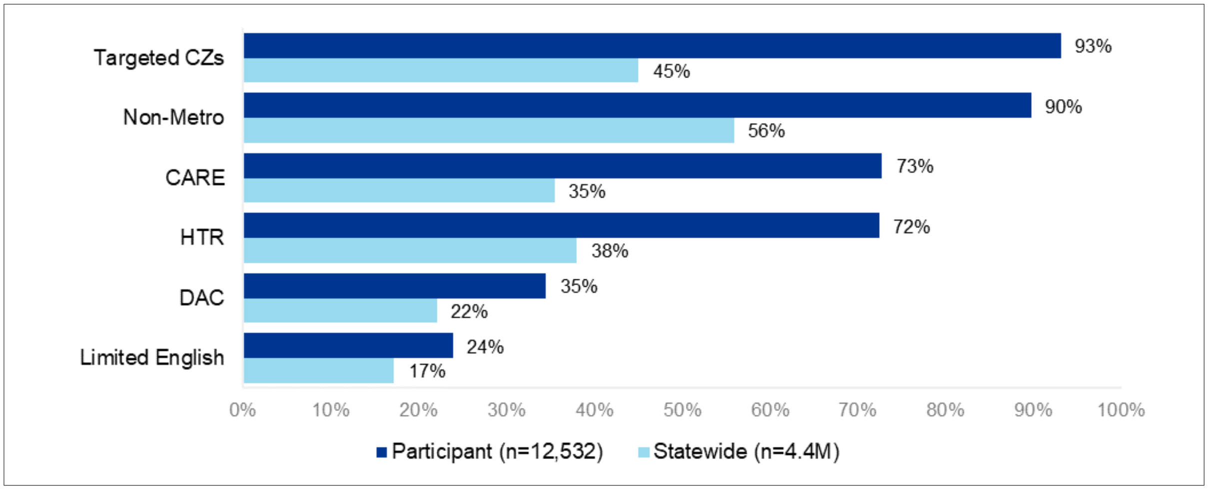
| Participant experience | Participants PY2021 (n=1,089) |
|---|---|
| Program satisfaction ratings on a 5-point scale | |
| Overall program experience (n = 854) | 87% |
| Experience with installation contractor Synergy (n =843) | 85% |
| Equipment upgrades and maintenance (n=808) | 84% |
| Information and education provided by program (n = 833) | 74% |
| Energy savings and cost reduction (n=818) | 71% |
| Non-energy impacts (e.g., increased comfort due to HVAC) (n=730) | 70% |

### 1.4.3.2 Participant characteristics

One of the primary research questions of the evaluation is to understand the types of customers that the programs served, including customers that are HTR and in DACs. DNV collected demographic information from utility customer information systems (CIS) and the American Community Survey (ACS) to inform these objectives. We used these data to calculate the proportion of customers that are HTR and in DACs and compared the values to the state proportions we calculated.

The CPUC definition of HTR includes customers that are on CARE and live outside of defined metro areas. We computed the percentage of participants on CARE and living outside metro areas and compared these to statewide proportions as well. Figure 1-6 summarizes the proportion of participants that are HTR and in DACs, on CARE, live outside metro areas, and are in hot climate zones (hot CZ), and compares them to the California proportions we computed.

**Figure 1-6. HTR and associated status of PY2021 program participants and statewide proportions**




The PY2021 Res DI programs reached a larger share of customers that are HTR, on CARE, reside outside of HTR-defined metro areas, and are in hot climate zones compared to the state proportions. The programs also served a higher proportion of customers that are in DACs compared to the state value. These results indicate that the programs have successfully reached customers that generally have difficulty accessing EE programs and face high energy burdens. Since the HVAC measures are also more effective in hotter climate zones, the programs have deployed their offerings effectively.

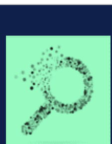
#### 1.4.3.3 Equitable evaluation

Though the CPUC ESJ goals were written after the PY2021 program launched, this evaluation provided an opportunity to assess the program relative to those goals. Program activities are consistent with one goal and more information is needed to assess consistency with the rest.

## 1.5 Recommendations

The key findings from the evaluation and the recommendations stemming from it are summarized in this section (Table 1-7).

**Table 1-7. Key findings and recommendations**

|  **Key findings** |  **Implications and recommendations** |
|---|---|
| 1. As in the past two program years, direct install smart thermostats have a low gross realization rate. | Although the claimed savings for smart thermostats were revised downwards by approximately 10% starting in PY2024, the continued low gross realization for this measure suggests that the savings need further revision.<br><br>The findings also suggest that programs consider improved customer/contractor training when installing smart thermostats in direct install programs. |

| Key findings | Implications and recommendations |
|---|---|
| 2. Direct install **fan motors** also continue to have low realization rates. | We recommend a new HVAC motor baseline study and a revision to the **fan motor replacement measure package** since its baseline fan motor efficiency is based on a 15-year old study. Together with this update, programs should review the criteria for installing these measures. |
| 3. Similarly, direct install **fan controls** have a low realization rate. | The **fan motor control measure package** savings are based on a 2012 SCE study. We recommend a review to understand why the savings based on that study are not realized and a revision of the fan control measure package savings methodology. Together with this review, the programs should re-assess the criteria for installing these measures. |
| 4. The water heating (aerator) measures included in the current evaluation also have a low realization rate. | There are two possible explanations for the low aerator realization rates: 1) inflated unit energy savings due to inaccurate assumptions in the deemed measure package of hot water consumption at sinks or electric water heater presence, or 2) the change in flow rate this is less than assumed or is uncertain. Both explanations require investigation and correction if necessary. |
| 5. Two of the three HVAC tune-up measures (HVAC fan repair and coil cleaning) delivered close to half of the claimed savings for each measure, while the third (HVAC RCA) only delivered 2% of the claimed savings for the measure. | This finding supports prior decisions to sunset the RCA measure. The measure should remain closed. |
| 6. Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the HVAC consumption and deliver savings during the summer peak demand hours and across all seasons. | Continue to include these measures in the residential HVAC program portfolio. |
| 7. The demographic profiles and evaluated NTGRs indicate that these programs are reaching the right population segments. | Maintain targeting and outreach to these customers. |

|  **Key findings** |  **Implications and recommendations** |
|---|---|
| 8. The programs' new integrated demand side management is yielding success. A higher proportion of participants was aware and enrolled in SCE's smart thermostat demand response program compared to non-participants. | Continue to offer information to increase awareness about SCE's demand response programs and offer to enroll participants in these programs at the time of energy efficiency installations. |
| 9. While customers were generally satisfied with the programs, with 87% reporting overall satisfaction, they reported somewhat lower satisfaction with the information and the benefits the programs provided. | Follow up to ensure installed equipment works as intended and provide better education and information, particularly for measures with behavioral aspects, to enable customers to receive the full benefits of the installations. |
| 10. Program activities were consistent with one of the CPUC's ESJ goals and more information is needed to assess consistency with the rest of the CPUC ESJ goals. | Establish an equity metric framework and specific equity- and access-related metrics for all programs. Where a quantitative metric is not practical, guide programs about what activities would be consistent with the ESJ goals. |

DNV

# 2 INTRODUCTION

## 2.1 Program description

California's investor-owned utility program administrators (PAs) have traditionally offered residential direct install (Res DI) programs to low- to moderate-income customers that do not qualify for low-income programs. These programs installed energy efficiency measures at no cost to reduce the financial and energy burden of these customers.

DNV evaluated two direct install programs, Residential Direct Install (SCE-13-SW001G) and Comprehensive Manufactured Homes (CMH) (SCE-13-TP-001) program, offered by Southern California Edison (SCE) in program year (PY) 2021. We evaluated these programs because of their high contribution to the portfolio kW savings claims and the associated contribution to summer reliability. The programs offered measures whose first-year net kW impact constituted about 15% of overall kW savings and 50% of residential workpaper-based deemed energy efficiency claims in the California Energy Data and Reporting System (CEDARS).

The first program served single-family homes, whereas the second targeted manufactured homes. Aside from the two housing types, the programs did not target other dwelling types, nor did they require participants to meet income requirements.

However, based on CPUC Decision 21-06-015,[21] SCE's PY2021 Res DI programs targeted customers that are:

- Hard-to-reach (HTR)
- In disadvantaged communities (DACs)
- In rural and tribal areas
- In public safety power shut off (PSPS) and wildfire zones
- In emergency load reduction program hot climate zones (9, 10, 13, 14, and 15)

In PY2021, the Res DI programs offered a comprehensive set of direct install heating, ventilation, and air conditioning (HVAC) measures. Additionally, the programs initiated an integrated demand side management (IDSM) program by enrolling qualified customers that installed smart thermostats into SCE's Demand Response (DR) Smart Energy Program. This is in line with CPUC Decision 07-10-032 directing utilities to offer IDSM that simplifies customer energy management decisions and allows customers to be more load responsive.[22] The programs also partnered with local water agencies to provide water-saving aerator measures.

Table 2-1 summarizes the measure offerings of the programs in PY2021. The programs did not install the same measure bundles for all customers. Measure bundles varied based on the existing equipment in the home and the eligibility requirements outlined in the CPUC measure packages. The measures and services provided by the programs included smart thermostats, duct test and sealing, brushless fan motor replacement, fan delay motor controllers, condenser coil cleaning, refrigerant charge adjustment, fan repair, and faucet aerators and showerheads.

[21] "Southern California Edison's Implementation Plan Comprehensive Manufactured Homes," cedars.sound-data.com, 12/23/2021, SCE EE Program Implementation Plan Template V2.0 (sound-data.com).

[22] CPUC, "Interim Opinion on Issues Relating to Future Savings Goals and Program Planning for 2009-2011 Energy Efficiency and Beyond," cpuc.ca.gov, 04/13/2006, https://docs.cpuc.ca.gov/published/FINAL_DECISION/74107.htm

**Table 2-1. Measures offered by program, PY2021**

| Program name and ID | Target | Delivery method | Measures |
|---|---|---|---|
| Residential Direct Install (SCE-13-SW001G) | Single-family homes | Direct Install | HVAC coil cleaning<br>HVAC fan controls<br>HVAC fan motor replacement<br>HVAC fan repair<br>Smart thermostat<br>Duct test and sealing<br>Refrigerant charge adjustment |
| Comprehensive Manufactured Homes (SCE-13-TP-001) | Manufactured or mobile homes | Direct Install | HVAC coil cleaning<br>HVAC fan controls<br>HVAC fan repair<br>HVAC fan motor replacement<br>Smart thermostat<br>Duct test and sealing<br>Refrigerant charge adjustment<br>Showerhead<br>Water heating faucet aerator |

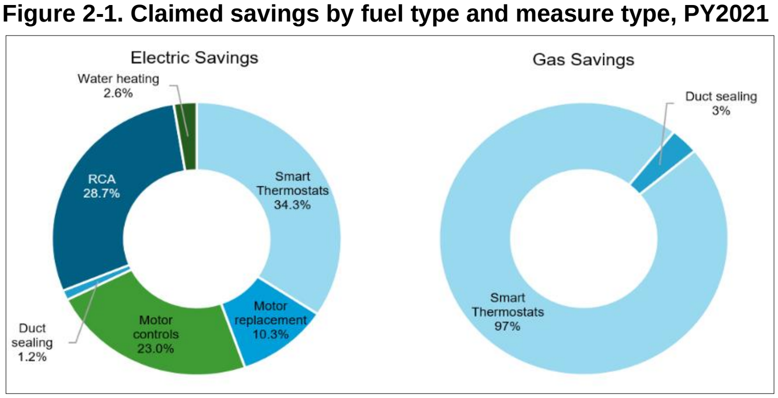
Table 2-2 summarizes the PY2021 claimed electric (kWh and kW) and gas (therm) savings, including the number of installations, and first year claimed gross and net kW, kWh, and therm savings for the two Res DI programs. The table shows that the majority (78%) of claimed savings come from the single-family direct install program.

**Table 2-2. Claimed savings by program and first year kWh, kW, and therms, PY2021**

| Program | Number of installations | | First year kW | | First year kWh | | First year therm | |
|---|---|---|---|---|---|---|---|---|
| | Electric | Gas | Gross | Net | Gross | Net | Gross | Net |
| Residential Direct Install Program | 21,697 | 11,580 | 3,608 | 2,497 | 7,142,707 | 5,675,298 | 163,734 | 144,578 |
| Comprehensive Manufactured Homes | 5,923 | 1,910 | 463 | 305 | 1,493,632 | 1,140,172 | 5,377 | 14,344 |
| **Total** | 27,620 | **13,490** | **4,071** | **2,802** | **8,636,339** | **6,815,470** | **169,111** | **158,922** |

Figure 2-1 summarizes the percent of claimed electric and gas savings for each measure installed by the PY2021 Res DI programs. All measures had electric claims while only smart thermostat and duct sealing had gas saving claims.[23] In both cases, the percent of savings claimed from smart thermostats is higher than for all other measures.

**Figure 2-1. Claimed savings by fuel type and measure type, PY2021**




[23] The PY2021 Residential Direct install programs did not claim gas savings for the aerators delivered by the programs. The absence of gas savings claims indicated that these measures were installed in customer homes with electric water heating. Future studies of this type should consider verifying water-heating fuels used in customer homes.

Table 2-3 summarizes the total number of claims by climate zone and housing type. The largest shares of installations are in the hot climate zones of 10 and 13. The two climate zones account for 80% of the single-family claims and 60% of the mobile home installations. Climate zone 13 has notable cooling and heating needs indicated by its normal (typical meteorological year – TMY) cooling and heating degree days (CDD and HDD),[24] which are both above 2,000.[25]

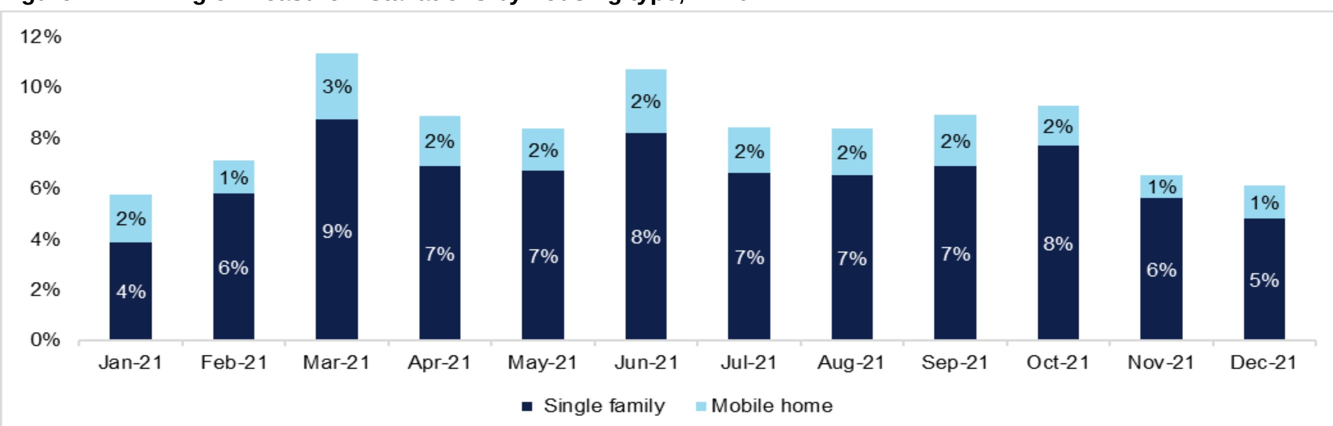
**Table 2-3. Total number of installations by climate zone and housing type**

| Climate Zone | Normal HDD | Normal CDD | Single family | Mobile home |
|---|---|---|---|---|
| 6 | 1,247 | 828 | 24 | 30 |
| 8 | 1,163 | 959 | 516 | 877 |
| 9 | 1,239 | 1,325 | 151 | 625 |
| 10 | 1,576 | 1,378 | 8,763 | 2,787 |
| 13 | 2,621 | 2,180 | 8,954 | 742 |
| 14 | 1,815 | 3,012 | 1,677 | 398 |
| 15 | 1,150 | 3,819 | 926 | 343 |
| 16 | 2,185 | 1,793 | 688 | 119 |
| **Total Res DI installations** | | | **21,699** | **5,921** |

Climate zones designated as hot by the 2021 Summer Reliability decision are shaded grey.[26]

Figure 2-2 summarizes the timing of PY2021 installations by program (home type). It indicates that the number of installations by month was consistent with slightly more homes served in the months of March and June. On average, the single-family program added approximately 1,800 participants per month while the manufactured home program added about 500 participants per month.

**Figure 2-2. Timing of measure installations by housing type, PY2021**




## 2.2 Evaluation objectives

The research impact objectives for the PY2021 Res DI programs include the following:

- Estimating the gross energy savings of the Res DI programs.
- Estimating the portions of the savings attributed to the programs.

[24] For assessing energy usage, power and utility companies monitor heating and cooling degree-days and compare weather forecasts to a location's Climate Normals. Understanding Climate Normals | National Oceanic and Atmospheric Administration (noaa.gov)

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

[25] Areas with the highest cooling and heating needs in the state have CDD and HDD values that are above 2,000.

[26] CPUC, "Phase 2 Decision Directing Pacific Gas And Electric Company, Southern California Edison Company, And San Diego Gas & Electric Company to Take Actions to Prepare for Potential Extreme Weather in the Summers Of 2022 And 2023," cpuc.gov, 12/2/21, https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M427/K639/427639152.PDF

- Determining the hourly savings shape of participants in the programs.
- Estimating the peak demand savings provided by the programs.
- Estimating the solar generation and load profiles of customers with on-site solar.
- Understanding program performance and participant characteristics.

# 3 METHODOLOGY

This section outlines the methodology DNV used to evaluate the PY2021 Res DI programs, including the data and methods used to evaluate claimed savings, program performance, and participation.

## 3.1 DATA

This section provides our data sources and a description of key data elements used in this year's evaluation.

### 3.1.1 Data sources

We used the following sources of data for the evaluation:

- **Tracking data** - We sourced information about program participation at the claim level from tracking data that SCE filed with the CPUC in the California Energy Data and Reporting System (CEDARS). We analyzed, cleaned, and re-categorized the data in preparation for program analysis and participant surveys. The tracking data was used to identify program participants, measures installed, and claimed (ex-ante) savings.
- **Program participant data** - We obtained program-related information, including details on installed measures and participants' contact information (names, emails, and phone numbers), at the customer account level from SCE. This information was used to understand participation patterns and assess program performance.
- **Energy use data (utility billing and Advanced Metering Infrastructure (AMI) data)** – We used billing and AMI data at the customer account level obtained from SCE to model energy consumption and estimate program savings and hourly savings shapes. We also used the billing data to identify those that are on discounted rates like CARE/FERA to aid in participation characterization.
- **Customer Information System (CIS) data** - We obtained information on customer locations and climate zones, and supplementary contact information from utility customer information tables. We used the information to understand participation patterns.
- **Onsite solar production data** - We collected data to estimate solar production from SCE. These included onsite photovoltaic (PV) system characteristics, such as system size (rated kW), type, location, tilt, orientation, and system location data (latitude and longitude). We also purchased solar irradiance data from Solargis[27] for the same purpose.
- **Weather data** - Weather data was sourced from the National Oceanic and Atmospheric Administration (NOAA) and climate zone (CZ) 2022 reference temperature files (CZ2022) to include in regression models accounting for weather sensitivity. CZ2022 provides typical meteorological year (TMY) weather data for select California weather stations that are useful for long-term weather normalization.[28] The study also used climate zone information available by zip code from the California Energy Commission (CEC). Data were at the hourly level for each station.
- **CalEnviroScreen** - The California Environmental Agency (CalEPA) calculates this metric, which provides a geographic picture of the environmental, public health, and socioeconomic conditions in California's 8,057 census tracts.[29] It enables a relative ranking of the pollution burdens and socioeconomic vulnerabilities of communities across CA. We used this metric to identify DACs for program performance assessment and an appraisal of DAC participation in Res DI programs.
- **U.S. Census data** - We supplemented participant information (location, language, and rental status) with block group level data from the American Community Survey (ACS) conducted by the U.S. Census Bureau.[30] We mapped this information to program areas to understand participation characteristics.

[27] Solargis, https://solargis.com/

[28] Weather normalized energy is the energy a building would have used under average conditions (also referred to as climate normals). The weather in a given year may be much hotter or colder than a building's normal climate; weather normalized energy accounts for this difference. Climate and Weather (energystar.gov).

[29] OEHHA, "Map of CalEnviroScreen 4.0 Indicators," oehha.ca.gov, https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

[30] U.S. Census Bureau. (2021). 2016-2020 American Community Survey Data, 5-Year Estimates.

- **U.S. Office of Management and Budget (OMB)** - We used the U.S. OMB's core-based statistical areas (CBSAs), which include the San Francisco Bay area, San Diego, Greater Los Angeles (Los Angeles, Orange, San Bernardino, Riverside, and Ventura counties), and Sacramento to define metro and non-metro regions. Being located in a non-metro region is one of the criteria used to identify HTR customers.
- **Program implementation plans (PIPs)** - We leveraged information from the PIPs that SCE developed for program performance review. A PIP details a program's design including targeted sectors, the program's goals, outreach strategies, and delivery plans.[31]
- **Program manager interviews** - We conducted an in-depth interview with the program implementer (Synergy) and the program manager at SCE to gather information on program design and execution.
- **Survey data** - We used data from primary research (surveys) to inform gross and net savings estimates, program performance, and to gain insight into customer demographics, participation, interests, and experience.

### 3.1.2 Measure bundles

The Res DI programs delivered measures in different combinations to participating customers. We assessed the tracking data to identify the extent of measure overlap from the program installations. The analysis indicated considerable measure overlap. As Figure 3-1 shows, for example, 37% of customers who installed a smart thermostat also installed fan controls. On average, mobile homes installed 1.9 measures while single-family homes installed an average of 1.7 measures.

**Figure 3-1. Measure percent overlap by home type for Res DI programs**

| | Coil cleaning | Duct sealing | Fan controls | Fan repair | Motor replacement | Refrigerant charge adjustment | Smart thermostat | Water heating (aerator) |
|---|---|---|---|---|---|---|---|---|
| Coil cleaning | 100% | 7% | 15% | 100% | 29% | 98% | 77% | 6% |
| Duct sealing | 2% | 100% | 18% | 3% | 12% | 36% | 66% | 17% |
| Fan controls | 0% | 2% | 100% | 1% | 21% | 22% | 82% | 4% |
| Fan repair | 93% | 7% | 20% | 100% | 28% | 92% | 76% | 8% |
| Motor replacement | 2% | 3% | 54% | 2% | 100% | 21% | 81% | 2% |
| Refrigerant charge adjustment | 4% | 4% | 32% | 4% | 12% | 100% | 66% | 3% |
| Smart thermostat | 1% | 3% | 37% | 1% | 14% | 20% | 100% | 3% |
| Water heating (aerator) | 1% | 11% | 33% | 2% | 6% | 14% | 54% | 100% |

### 3.1.3 Energy consumption data

We obtained energy consumption data from SCE at multiple levels of granularity including monthly, daily, and hourly. Monthly billing data were used as a means of identifying non-participants (those without any utility-sponsored measures)

[31] DNV referenced the following two PIPs for the evaluation: SCE EE Program Implementation Plan Template V2.0 (sound-data.com) and SCE EE Program Implementation Plan Template V2.0 (sound-data.com).

whose energy use patterns can help inform baseline energy consumption. The daily data served to fine-tune the identification of non-participants and served as the basis for site-level modeling. Additional information on this process is described in Appendix F, Section 6.6. Finally, hourly data were included in models used to estimate the effect of the program/measure on hourly energy demand.

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

To prepare the hourly electric data, we also used screening procedures. First, we excluded days missing more than four hourly reads. Second, we excluded days with zero total consumption. After aggregating the data to the daily level, we included data only for customers with at least 90% of daily values in both the pre- and post-program period. After screening the data, we checked it against billing records to ensure its integrity.

Table 3-1 presents the number of customers for whom consumption data were considered and used in the evaluation. The table indicates the starting household counts from the tracking data considered for use in the evaluation and for whom we requested and received data; the number of customers without onsite solar (not net-metered), and finally customers with interval (AMI) data with the requisite pre- and post-installation data of at least 328 days available for the analysis.

**Table 3-1. Customer counts used in the evaluation, PY2021**

| Participant data attrition | SCE |
|---|---:|
| Customers with PY2021 Res DI installations | 14,259 |
| Customers for whom data was requested | 13,834 |
| Customers for whom some data was received | 13,798 |
| Customers with data and not net-metered | 8,635 |
| Customers with matched and sufficient data used in the analysis* | 8,525 |

*** Customers without solar (net-metering) and at least 90% of pre-and post-installation period data.**

### 3.1.4 Weather data

We soured weather data from the National Oceanic and Atmospheric Administration (NOAA) and climate zone 2022 reference temperature files (CZ2022) from CALMAC to include in regression models accounting for weather sensitivity.[32] CZ2022 provides typical meteorological year (TMY) weather data for select California weather stations that are useful for long-term weather normalization. The study also used climate zone information available by zip code from the CEC.[33] Data were at the hourly level for each station.

We applied the following data filtering protocols in line with CalTRACK recommendations and used weather data from weather stations that have complete and usable data in the analysis.[34] The filtering protocols include:

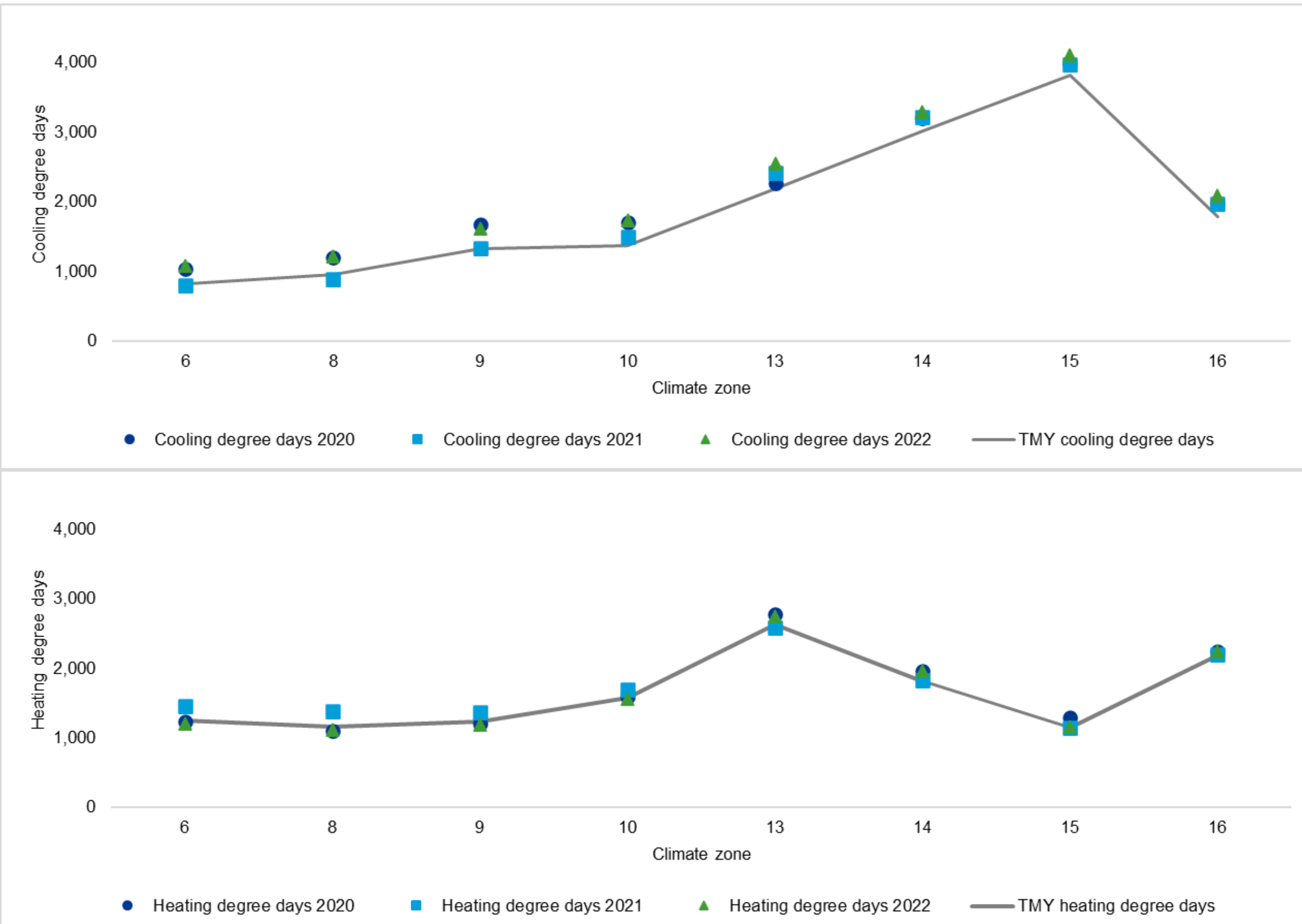
- Interpolating gaps of up to six consecutive hours
- Calculating and using daily average temperatures for days with at least 12 hourly temperature reads
- Including stations that have at least 90% of the data for each year needed in the analysis

[32] National Oceanic and Atmospheric Administration Hourly Weather Data; California Energy Commission Title 24. https://www.energy.ca.gov/title24/; http://www.calmac.org/weather.asp.
[33] Building Climate Zones by Zip Codes | California Energy Commission; https://www.energy.ca.gov/media/3560
[34] http://docs.caltrack.org/en/latest/methods.html#section-2-data-management

Figure 3-2 provides a summary of cooling degree-days (CDD) and heating degree-days (HDD) used in the study. We used 2022 TMY data to weather normalize consumption in this study. In general, weather normalization controls for the effect of weather variation by putting energy consumption on the same normal weather terms across time.

The 2022 TMY values reflect more recent weather patterns including warmer summers and more mild winters. The figure indicates climate zones 13 through 16 have significant cooling needs while 13 and 16 also require heating. The figure also illustrates the variation of the actual weather CDDs and HDDs over the analysis period relative to normal CDDs and HDDs that are used to state energy consumption on the same weather basis. Such weather normalization facilitates the comparison of energy consumption after controlling for the effect of weather.

**Figure 3-2. Summary of weather data PY2021**




## 3.2 Residential Direct Install primary data collection

The study collected primary research data using web surveys to inform gross and net savings estimates, assess program performance, and gauge participant characteristics and interests. DNV administered surveys among single-family and manufactured home participants and non-participants. We issued surveys to all customers with valid email addresses and set a minimum goal of 300 completed responses by program to inform program attribution, awareness, experience, and customer characteristics. Our goal was to have a sufficient sample size to estimate NTGRs and draw inferences on different dimensions of performance at the program level with a ±10% relative precision at the 90% confidence level.

Unlike in prior program years, SCE was the only IOU that offered Res DI programs. Synergy implemented the two programs and used its own staff to install program measures. As a result, we did not conduct contractor surveys.

The following sections provide additional details on the participant and non-participant surveys we administered for the evaluation of the PY2021 Res DI programs.

### 3.2.1 Participant surveys

We administered participant surveys to customers who were the decision makers for Res DI program installations in their households and accepted free installed HVAC and water heating measures. The primary objective of these surveys was to inform estimates of free-ridership (and the complementary NTGRs and program attribution estimates).[35]

Surveys also gathered information on participant satisfaction, their perception of the purpose of the programs and program benefits, demand response participation and interest, clean technology adoption and interest, and dwelling characteristics and participant demographics.

### 3.2.2 Non-participant surveys

We also surveyed non-participant customers from a matched-comparison group used in the consumption data analysis. The matched comparison households are a set of customers who have been matched to the participants based on their energy consumption patterns, but who have not participated in the Res DI or other utility energy efficiency programs. The primary objective of the non-participant surveys was to provide reference points to energy use behavior, demand response program participation, adoption of clean technology, and the prevalence of non-program smart thermostats.

### 3.2.3 PA and implementer interviews

We also conducted in-depth interviews among PA program staff and the program implementer (Synergy Companies) to gain a better understanding of how the programs were rolled out in PY2021. The data collected was used to supplement information the administrator provided in the program implementation plans (PIPs) and inform other data collection activities. DNV conducted the interviews via Microsoft Teams. We gathered information on a variety of program outreach and delivery-related topics including participation rules, program information tracking, installation decisions, and the programs' efforts to encourage deeper savings. Table 3-2 summarizes the primary data collection sources used to inform the research.

**Table 3-2. Primary data collection sources**

| Respondent group | Data collected | Frame source | Mode | Stratification approach | Sample size | Timing |
|---|---|---|---|---|---|---|
| **Program manager and implementer** | Program delivery, participation rules, installation decisions, and program information tracking | Utility program staff and implementers | In-depth Interviews | N/A | Census (100% of staff invited to participate) | Fall 2022 |
| **Participant** | Program influence / NTG, program experience, and demographic data | Program tracking data | Web survey | Program, HTR/DAC | Census minimum n=300 by program | Winter 2022 |
| **Non-participant** | Household characteristics, smart thermostat installation, and clean technology adoption | Matched comparison group | Web survey | N/A | Census minimum n=300 | Winter 2022 |

35 Free-riders are participants that would have installed the same measures in the absence of the program. They are referred to as free-riders because they are receiving incentives from programs for actions they would have taken without the programs' existence.

### 3.2.4 Survey mode and sample disposition

**Participant and non-participant occupant surveys—**We administered web surveys among participants and matched non-participants over an approximate 10-week period from November 2022 to January 2023. The sample frame for participant surveys was customers who had received direct install residential measures in PY2021. The sample frame for non-participant surveys was drawn from the set of matched comparison households used in the consumption data analysis. Matched comparison households are a set of non-participants who have been matched to the participants based on multiple variables including location and energy consumption patterns.

We adopted a census approach for the participant surveys that included all customers with available email contact information who were not on the SCE do-not-contact list. We also drew a random sample from the matched comparison households, which included customers with email information and not on the SCE do-not-contact list, for the non-participant survey. Five rrespondents were offered the chance to win a $100 gift card as an incentive to complete the survey. Survey invitees were encouraged to complete the survey, and two reminders were sent through the survey fielding period. The surveys included both CPUC and SCE branding to boost response. The survey also included a link to a dedicated page on the CPUC website that allowed respondents to validate the sponsor and the legitimacy of the surveys.

The sample disposition for the participants and non-participants is summarized in Table 3-3. Survey response rates were comparable to PY2020. In 2020, we achieved response rates of 11% among SCE participants and 5% among non-participants compared to 13% among participants and 6% among non-participants in PY2021.

**Table 3-3. Sample disposition for participant and non-participant occupant surveys, PY2022**

| Disposition | Participants | Non-participants |
|---|---:|---:|
| Invites sent | 9,382 | 72,550 |
| Not started | 8,136 | 67,901 |
| Incomplete | 253 | 935 |
| Completed | 993 | 3,714 |
| Response rate | 13% | 6% |

## 3.3 Savings evaluation approach

This section provides the approach that DNV used to estimate gross savings. It details the consumption data analysis used to estimate whole home savings and the methods used to disaggregate these savings into measure level savings. It also provides adjustments made to account for the prevalence of smart thermostats among non-participant homes.

### 3.3.1 Gross savings estimates

We used consumption data analysis to estimate whole home savings. Since direct install programs typically deliver multiple measures, it is necessary to decompose whole home savings into measure-specific savings. One approach is to use regression-based statistical decomposition of whole home consumption changes. Statistical noise and multicollinearity make this a challenging undertaking. The physical incremental effect of a single measure depends on what other measures are also installed, complicating this approach further.

Another approach, which we used, is to allocate whole home savings to the multiple installed measures based on engineering estimates. To the extent practical, we also used separate consumption data analysis for direct install homes that received single measures to confirm the allocation of the whole home savings. A description of the approach we used to obtain robust measure-specific savings under these conditions is detailed in Section 3.3.3.

### 3.3.2 Comparison group thermostat installation adjustment

We adjusted estimated smart thermostat savings for direct install programs to account for the installation of this measure among matched comparison households. Our non-participant survey included a question that asked respondents to indicate whether they had installed smart thermostats before 2020 and at any time from 2020 through 2022. Non-participant installations from 2020 through 2022 overlap with participant installation and post periods. If comparison group smart thermostat installations are assumed to have the same savings effect in the matched comparison households as program thermostats, then their presence during this period will have the effect of diminishing the magnitude of estimated smart thermostat savings for participants. The adjustments to control for this effect are detailed in Appendix G, Section 6.7.2.

### 3.3.3 Decomposition of whole home savings

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

Engineering model estimates for this purpose are derived from simulations of residential energy use based on California Database for Energy Efficiency Resources (DEER) prototypes in eQUEST, an engineering simulation engine. The simulation models, discussed in more detail in Section 3.3.4 below, provide estimates of the percent reduction in load from baseline use by climate zone and housing type, for individual measures and for measure bundles offered by direct install programs.

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

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

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

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

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

Here:

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

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

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

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

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

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

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

### 3.3.4 eQUEST engineering modeling

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

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

- The pre-participation energy consumption profile of participants
- Data for nonprogrammable thermostats from RASS for baseline thermostat schedules
- Adjustments of lighting and plug load density.

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

- **Coil cleaning**: Cooling EIR adjustment (baseline EIR = efficient EIR x 1.065) and coil bypass factor adjustment (baseline BF = efficient BF * 0.99574) based on the HVAC3 (PY2013-14)[36] and HVAC5 (PY2013-14)[37]
- **Smart thermostats**: setpoints/degrees of setback so that cooling and heating savings are 2% to 3%, in line with PA workpaper estimates
- **Fan motor replacements**: supply kW (0.00065 to 0.0004 kW/cfm) and delta-T adjustments (2.054 F to 1.012 F) based on the 2018 HVAC evaluation
- **Fan controls**: cooling EIR adjustment (efficient EIR = 0.88428 * baseline EIR) from deemed WP WPSDGEREHC0024_R3_Res Fan Delay Controller that is based on an SCE study, adjusted to reflect claimed kWh savings reported in the tracking data
- **Duct test and seal**: duct air loss reduction (from 33.7% to 15% for single family and mobile homes) from deemed WP, SWSV001-01, adjusted to reflect claimed kWh and therm savings reported in the tracking data
- **Refrigerant charge adjustment**: Cooling EIR adjustment (baseline EIR = efficient EIR x 1.0106976) based on from the HVAC3 (PY2013-14) report

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

[36] https://www.calmac.org/publications/HVAC3ImpactReport_0401.pdf
[37] https://www.calmac.org/publications/HVAC5_2013-14_Introduction_and_Data_Dictionary.pdf

developed. For faucet aerators and showerheads, we used tracking savings in the disaggregation models. For fan repair, we used a proportion, based on the tracking data, of the coil cleaning simulated savings in the measure models.

## 3.4 Savings shape

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

We estimated hourly load and savings shapes for homes that received Res DI measures using site-level (weather normalization) regression models and an hourly DID method. The site-level hourly regression models we estimated were based on pre- and post-program hourly data and take the following form:

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

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

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

$\alpha_{ish}$ = customer-specific baseload for hour *h* and season *s*

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

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

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

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

$\dddot{H}_{ij}$, $\dddot{C}_{ij}$ = HDD and CDD based on TMY/CZ2022 and the selected base used in the regression

We applied this approach to a full year of hourly data using data from both participant and comparison group (non-participant) households and provided predictions of consumption for all hours of the year based on TMY/CZ2022 weather data.

We then used predicted consumption for all hours from the pre- and post-period in a DID framework to produce an hourly load savings shape. We fit the DID model using the methodology as published in Chapter 17, section 4.4.5 of the Uniform Methods Project.[38] The estimated hourly savings load shape is given by:

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

$\Delta Y_{jh}$ = treatment effect for hour *h* in day *j*

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

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

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

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

[38] Office of Energy Efficiency & Renewable Energy, "Uniform Methods Project: Determining Energy Efficiency Savings for Specific Measures, energy.gov, https://www.energy.gov/eere/about-us/ump-protocols

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

## 3.5 Onsite solar generation

Impact calculations based on pre- to post-program installation data require energy use information. Customers with onsite solar are net-metered,[39] meaning their actual energy use is unknown. They have typically been excluded from estimates of average energy savings. Evaluation based on a pre- to post-program installation energy consumption data analysis assumes that solar customers save as much energy as their non-solar counterparts. This approach will become increasingly untenable because:

- The number of customers with onsite solar has been and will continue to increase, which translates into a large number of EE participants not used to assess EE savings.
- There is information that suggests that solar customers use energy differently than non-solar customers. There may be a take-back effect where solar customers use more electricity than before they had solar.

In an effort to address this issue, we explored an approach to estimate solar generation and construct whole house electricity use at hourly and daily resolution.

We used DNV's Solar Resource Compass (DNV SRC),[40] a program that uses solar system characteristics, geographic location, and solar irradiance data, to simulate hourly (8,760) energy generation. DNV SCR uses actual year solar irradiation (as opposed to using typical meteorological year, or TMY, solar irradiation) and detailed system data to provide results that reflect observed weather conditions.

For most sites, SCE provided the following characteristics needed for the simulations: premise identifiers, system tilt,[41] system azimuth (orientation),[42] and nameplate rating.[43] We used the premise identifiers to obtain site coordinates (latitude and longitude) from CIS data that is provided to the Energy Division on an annual basis, or from a geocoding process applied to SCE customers' addresses where SCE site coordinates were not available.

For sites with non-missing system characteristics, we created a distance matrix and performed a cluster analysis to output the cluster centroid coordinates, with the purpose of assigning the appropriate solar radiation data associated with the cluster centroid. The distance between the selected site and its cluster centroid is 50 km or less to strike a balance between the cost of acquiring solar data and the accuracy loss from sites that are far from the centroid.

We then estimated whole house electricity use on an hourly basis for calendar year 2020 using the simulated hourly generation data and utility provided net metered hourly kWh (kWh delivered minus kWh received) data. The following equation captures the estimate:

Estimated whole house kWh at hour $i$ = NEM kWh from AMI at hour $i$ + kWh from onsite solar at hour $i$

Hour $i$ runs between 1 (hour ending at 1 am on January 1 – the first hour of the year) and 8,760[44] (hour ending at hour 24 on December 31, the last hour of 2020).

[39] Net metered electricity is the electricity from the grid minus the electricity produced onsite minus the electricity supplied to the grid. It can be positive or negative depending on the relative size of each of the three components.

[40] Please visit the DNV Solar Resource Compass page at https://src.dnv.com/

[41] System tilt, or system angle, is the slope angle (the number of degrees from the horizontal plane) at which solar panels are mounted to face the sun.

[42] System azimuth is the direction in degrees in which the panels face. South is 0º and due North is 180º.

[43] Nameplate rating is the installed capacity in kW. In this context, this is the highest hourly energy output that the system is expected to deliver.

[44] Year 2020 was a leap year. Non-leap years have 8,760 hours, and leap years have 8,784 hours. We analyzed 2020 as if it was not a leap year, to stay consistent with the solar simulation software.

## 3.6 Program attribution

This study also examined PA-program influence on Res DI measure installations to understand what percentage of the installations would have occurred in the absence of the programs, or what percentage of installations could be attributed to free-riders (participants that would have installed the same measures in the absence of the program). Gross measure savings estimate the change in energy use due to program participation, regardless of why customers participated, while net measure savings estimate the change in energy use without free-riders.

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

We surveyed participants who were decision makers for single-family and mobile home program installations.[45] From the survey responses, we calculated the level of free-ridership and its complement, the proportion of program installations that could be attributed to the programs.

Our approach focused on assessing three dimensions of free-ridership: timing, quantity, and efficiency. Taken together, these dimensions allow for estimates of net energy (kWh) savings attributable to each measure, because those savings depend on the number of measures installed (quantity), the efficiency of the measures (efficiency), and whether the measures would have been installed at a similar time or later without the program (timing).

As alluded to above, the timing question asks how soon each measure would have been installed without the program. The program gets full attribution for any measure that would not have been installed at all, and it gets partial credit for accelerating the timing if respondents noted any measure installations would have been delayed (or installed later) absent the program.

The efficiency question applies to the efficient measures installed by the programs for which there is a standard efficiency version in the market. In this study, these are smart thermostats and fan motors. The efficiency question gives the program full credit for the measure if the respondent indicates they would have installed nothing or a standard efficiency measure in lieu of the efficient program measure.

The quantity question asks how many units would have been installed absent the program. This question applies to the showerhead and faucet aerator measures only but not to all other measures received by single-family and mobile home participants, who were limited by the programs to a single installation of each measure type per home. The quantity question gives the program credit if the respondents indicate they would have installed fewer measures absent the program.

Appendix J, Section 6.10 provides details on how participant survey responses were scored to derive free-ridership values.

## 3.7 Program performance

In this section we discuss approaches we used to examine how the Res DI programs functioned and the equity implications of their operations.

### 3.7.1 Program operation

We assessed Res DI program performance using data collected from the following sources:

45 To assess measure installation decision-making in the absence of the program, participants were provided with an estimate of the cost to have the measure installed. A table of the cost estimates we used for this purpose is provided Appendix I.

- Program Implementation Plans (PIPS)
- The program tracking data
- CIS information
- ACS data
- Customer and program manager surveys
- PA and implementer in-depth interviews

Based on these sources of information, we examined three broad program dimensions including program design, program outreach and marketing, and various elements of program delivery (such as participant experience and IDSM). Table 3-4 presents the research questions that we answered using this data.

**Table 3-4. Program performance research questions by topic area**

| Topic area | Questions answered |
|---|---|
| **Program design** | • What was the purpose of the programs?<br>• Who did they intend to serve?<br>• What measures and services were offered?<br>• What barriers did the programs intend to address?<br>• What strategies did they use to overcome the identified barriers? |
| **Program outreach and marketing** | • How did the programs raise awareness of the Res DI programs?<br>• How did the programs conduct recruitment and engagement to increase participation? For example, did the kinds of measures installed help with recruitment? If so, how? |
| **Participant experience** | • Are customers satisfied with the programs, including the information programs provided, the installation contractor, installed equipment, energy savings and cost reduction, and non-energy impacts (noise, air quality, safety, comfort)?<br>• Do the participating customers understand the reasons for the no-cost direct install programs?<br>• What were the drivers of program participation?<br>• What barriers to participation did customers face? |
| **IDSM** | • Is the Residential Direct Install Program raising awareness and increasing enrollment in SCE's smart thermostat DR program?<br>• Are the awareness and participation of program participants in DR programs different from non-participants?<br>• What are the barriers to enrollment in SCE's smart thermostat DR program? |
| **Cost effectiveness (CE)** | • What are the reported cost effectiveness (TRC) values?<br>• How do these compare to calculated TRC values based on evaluated savings? |
| **Barriers to program expansion** | • What were the market barriers that limited program participation?<br>• What other barriers existed that also limited program expansion? |
| **Program data tracking quality** | • Did the PAs provide program tracking data that are reasonably complete, timely, and accurate?<br>• Did they have contact information for participating customers, property managers, decision-makers, and contractors? |

### 3.7.2 Equitable evaluation

This is the first year where evaluations focused on the program rather than the measure level. This created an opportunity to conduct a "process" evaluation of the programs in relation to the CPUC's *Environmental and Social Justice Action Plan (ESJ Plan) goals.*[46] Although these goals were not established until 2021, after the evaluated programs were designed, this evaluation provides a baseline which future program implementations can seek to exceed and a foundation for recommendations that will help the programs do so. DNV's equitable evaluation framework tracks the principles and relevant CPUC ESJ goals: 1, 2, 3, 4.1, 5, 6.1, 8, and 9.

## 3.8 Participant characterization

To characterize program participation, we reviewed program implementation plans (PIPs) and analyzed information from customer surveys and implementer interviews, the utility customer information system (CIS), and the American Community Survey (ACS). Using these sources, we examined the percentage of participants that resided in areas targeted by the program, including rural areas, hot climate zones, and DACs. We also used these data to assess the demographic distribution of customers, including the percentage of HTR customers, renters, and those on CARE/FERA. Table 3-5 itemizes the research questions that we sought to answer to evaluate these metrics.

**Table 3-5. Participant characterization research questions by topic area**

| Topic area | Questions answered |
|---|---|
| **Demographic distribution of participants** | • What percent of participants resided within the targeted geographic areas?<br>• What percent of participants were renters?<br>• What percent of participants were on CARE/FERA?<br>• What percent of customers did not use English as their primary language at home? |
| **HTR/DAC assessment** | • What percentage of participants were HTR/DACs?<br>• To what extent were the programs serving a lower-income population not eligible for income assistance services?<br>• What percentage of energy savings were from the HTR/DAC participants? |
| **Participation in other programs** | • What percent of participants were able to participate in other residential EE and DR programs based on information from the DI programs?<br>• What percent of customers did the programs enroll in DR programs?<br>• What were the barriers to enrolling customers in DR programs? |
| **Clean technology adoption** | • To what extent were customers using clean technologies?<br>• Are customers considering or planning to purchase clean technologies in the next two years? |

46 California Public Utilities Commission, "Environmental & Social Justice Action Plan," cpuc.ca.gov, April 7, 2022 https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/news-and-outreach/documents/news-office/key-issues/esj/esj-action-plan-v2jw.pdf

# 4 FINDINGS

## 4.1 Comparison group assessment

DNV requested account level data on household characteristics including household composition by age, household size, home ownership, and income for participants and matched non-participants. These data represent a combination of data drawn from the PA customer information systems and third-party customer data acquired by the PAs. We assessed balance from matching using load markers, tenure, and the following household demographic characteristics provided by the PAs:

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

A comparison of the distributions of these household characteristics for participants and their matched non-participants shows good correspondence between the two groups and indicates that the selected non-participants provide a solid basis for controlling the effect of program exogenous changes on household energy consumption. Below are summary distribution charts for household composition (Figure 4-1) and household size (Figure 4-2). Additional charts that compare the distribution of participants and their matched non-participant counterparts by home ownership and income are included in Appendix F, Section 6.6.3.

**Figure 4-1. Comparison group assessment by household composition**

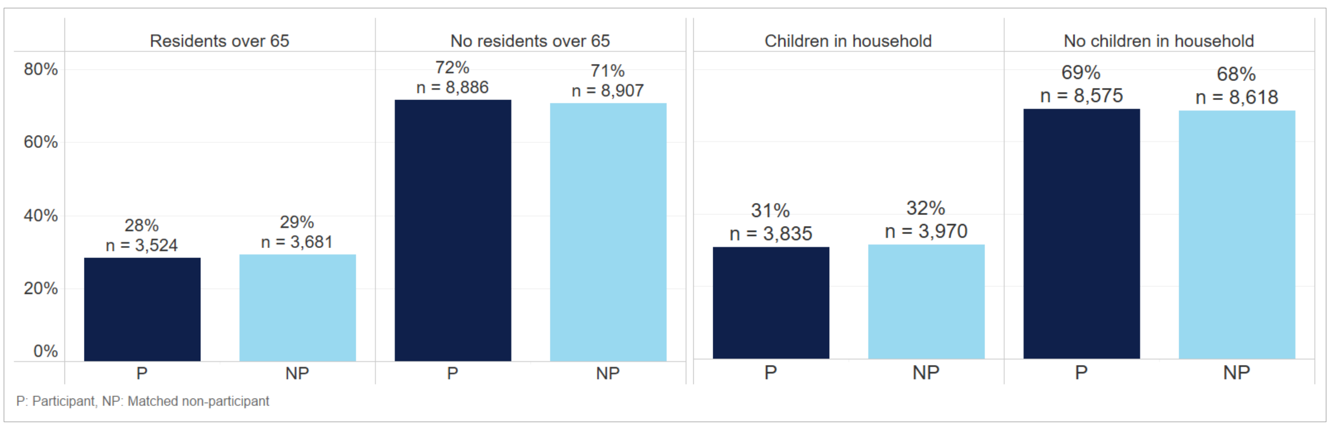
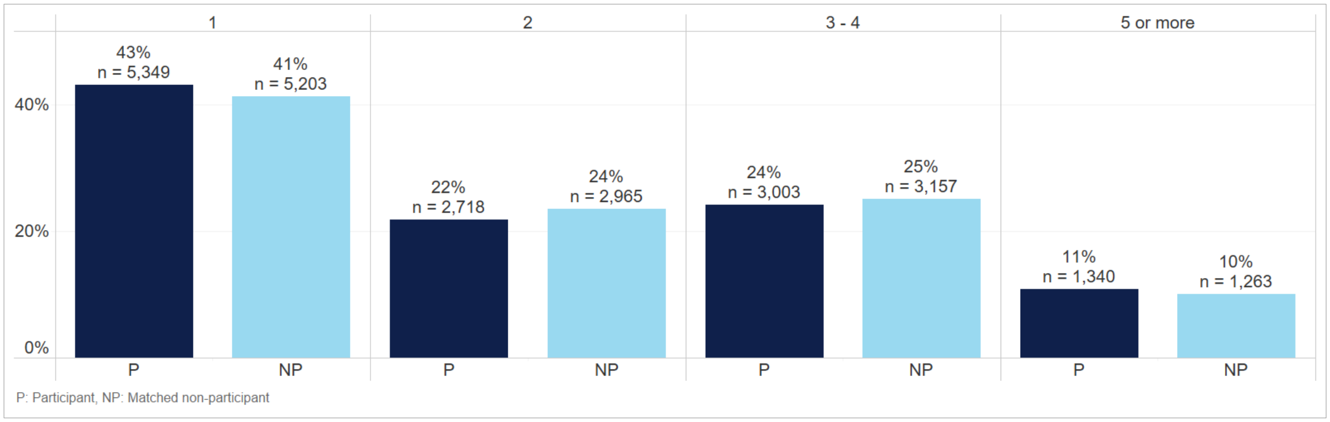


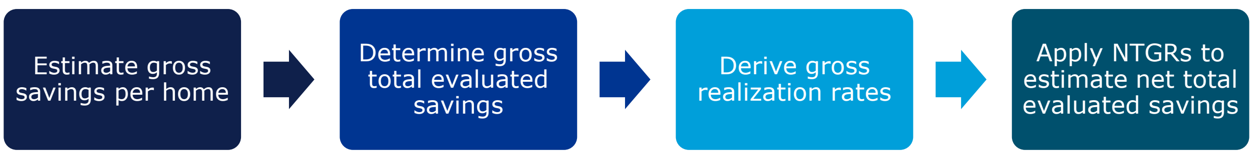
**Figure 4-2. Comparison group assessment by household size**




## 4.2 Impact results

This section presents estimated electric (kWh) savings from residential HVAC measure installations by housing type and climate zone. Whole home savings estimates are allocated proportionately to measures installed at the house. Measure-level savings are combined with tracked installation counts to generate gross evaluated savings and gross realization rates within SCE's service territory. Applying NTGRs to gross evaluated savings generates net evaluated savings as shown in Figure 4-3.

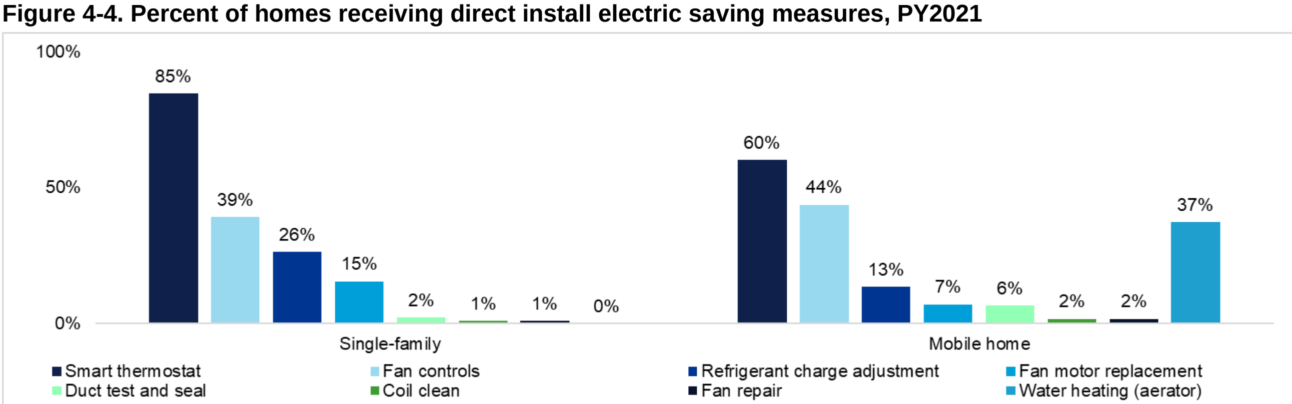
**Figure 4-3. Impact evaluation approach**




### 4.2.1 Whole home savings

In this section, we provide the measures installed through Res DI programs and present whole home savings, which are the basis of disaggregated measure level savings. Direct install programs offered different mixes of HVAC and other energy efficiency measures. Figure 4-4 provides the percent of households that received measures with electric savings claims by dwelling type. Most single-family and mobile homes installed smart thermostats. Fan controls were the next most common measure for both dwelling types. Mobile homes also installed small water heating measures while single-family homes did not.

**Figure 4-4. Percent of homes receiving direct install electric saving measures, PY2021**



The mix of electric measures varied by dwelling type. Most measures were installed with other measures, however, nearly half of the single-family homes that installed a smart thermostat did not install any other measure and 25% of the mobile homes that installed a smart thermostat did not install any other measure (Figure 4-5).

**Figure 4-5. Percent of direct install measures installed alone and in bundles by dwelling type, PY2021**

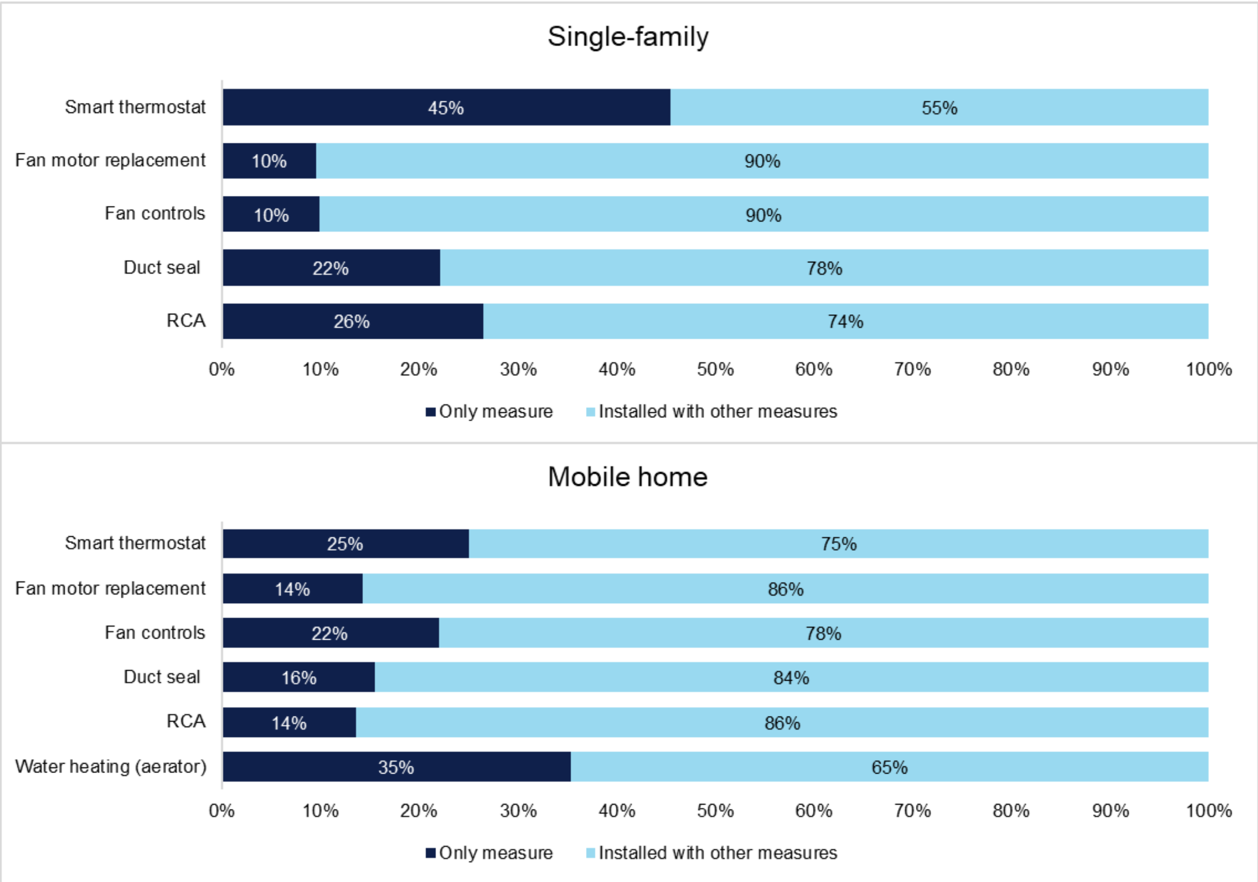
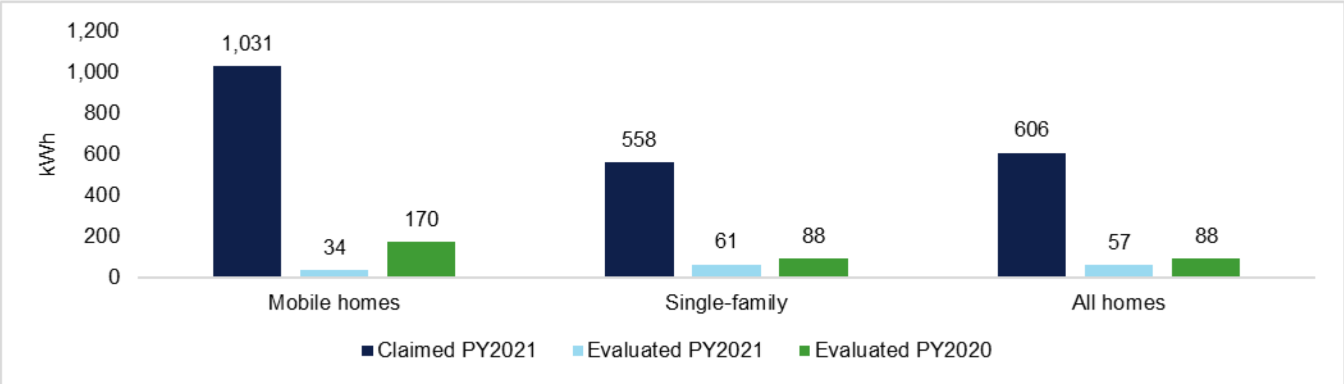



Figure 4-6 provides PY2021 estimated whole home electric savings compared to claimed savings for the Res DI programs by dwelling type. The figure also includes evaluated savings for PY2020 direct install programs for comparison. Whole home savings are distributed to measures proportional to engineering model savings as discussed in the methods. Mobile homes savings decreased considerably for PY2021 while single-family savings stayed roughly of comparable magnitude.

**Figure 4-6. Claimed and evaluated whole home savings for direct install programs, PY2021**



## 4.2.2 Measure group savings

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

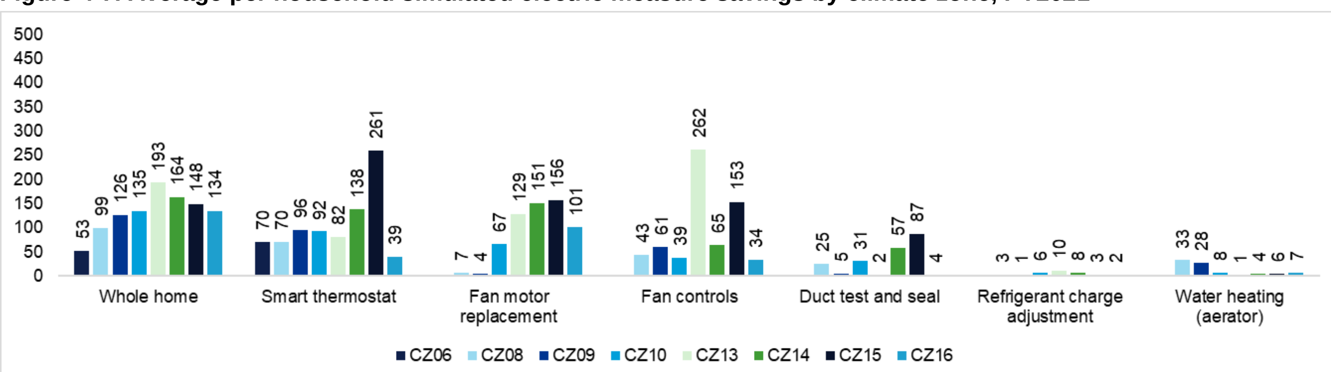
### 4.2.2.1 Engineering estimates

Engineering model savings are derived from a simulation engine that uses prototype models to generate measure savings for different dwelling types, climate zones, and retrofit conditions. The prototypes used to simulate savings were calibrated to reflect the pre-installation period consumption profiles of participants.

These calibrated values along with the best data available from workpapers, studies, and previous evaluation findings served as inputs in the simulations used to estimate the impact of the residential HVAC measures under study by dwelling type and climate zone. The individual simulated engineering measure savings as a percent of the simulated bundle of measures installed at each site were used to allocate the household pre-post difference from the consumption data analysis to the individual measures. Allocation is performed at the site level based on the site-level whole home savings.

Figure 4-7 provides the average engineering measure savings estimates by climate zone used to allocate whole home savings. The values reflect simulation measure savings that vary by climate zone. For example, smart thermostats installed in climate zones 14 and 15 have higher simulated savings than those installed in climate zones 6 and 8 while fan controls installed in climate zones 13 and 15 have substantially higher simulated savings than those installed in other climate zones.

**Figure 4-7. Average per household simulated electric measure savings by climate zone, PY2021**




### 4.2.2.2 Measure savings estimates

Figure 4-8 provides claimed and evaluated measure-level savings per household for all Res DI measures for PY2019 through PY2021. The claimed savings (left three columns for each measure) and evaluated savings (right three columns for each measure) are of similar magnitude across the three program years and the evaluated savings are lower than claimed in all years. Four measures evaluated in PY2021 (fan repair, coil cleaning, RCA, and water heating measures) but not in the prior program years are not included in the figure.

**Figure 4-8. Comparison of claimed and evaluated direct install measure savings per home**

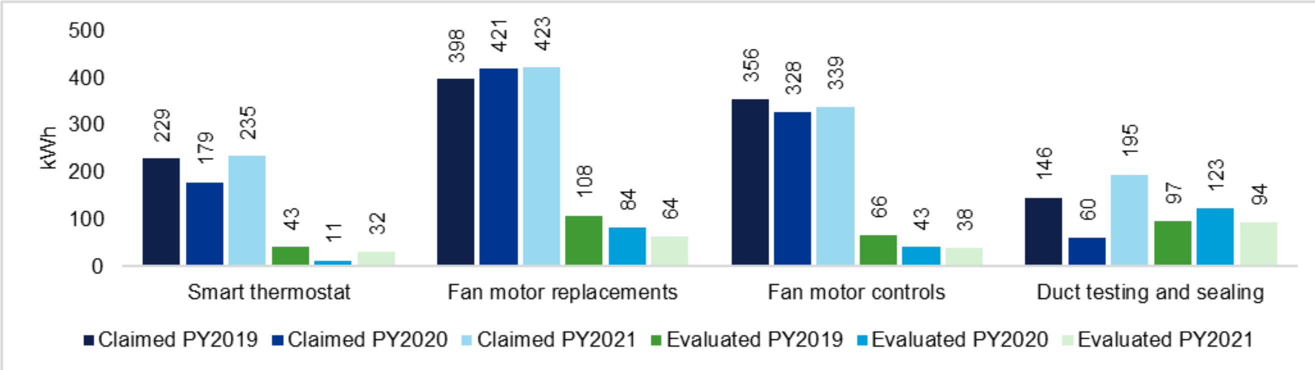


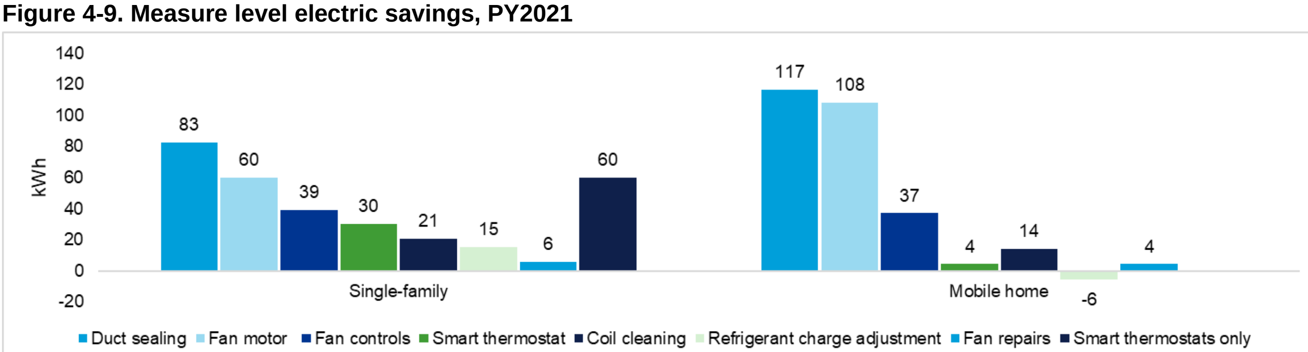

Table 4-1 provides the estimated savings per home along with their standard errors and p-values. The table indicates that all measure savings except RCA and water heating are statistically significant at the 90% confidence level, though measures savings were estimated with precision levels between 0.6 and 0.75.

**Table 4-1. Direct install electric whole home and measure-level savings models, PY2021**

| Model type | Model estimates | | | |
|---|---|---|---|---|
| | Savings (kWh) | Standard error | Relative precision | P-value |
| Whole home | 51.3 | 21.7 | 0.69 | 0.02 |
| Smart thermostats | 32.2 | 14.6 | 0.74 | 0.06 |
| Fan motor replacement | 64.4 | 25.8 | 0.66 | 0.01 |
| Fan motor controls | 38.3 | 14.6 | 0.62 | 0.01 |
| Duct testing and sealing | 93.6 | 34.3 | 0.60 | 0.01 |
| Coil cleaning | 20.1 | 7.9 | 0.67 | 0.01 |
| Fan repair | 5.9 | 2.5 | 0.73 | 0.03 |
| Refrigerant charge adjustment | 13.2 | 8.9 | 1.08 | 0.13 |
| Water heating (aerators) | 3.0 | 29.0 | 22.91 | 0.94 |

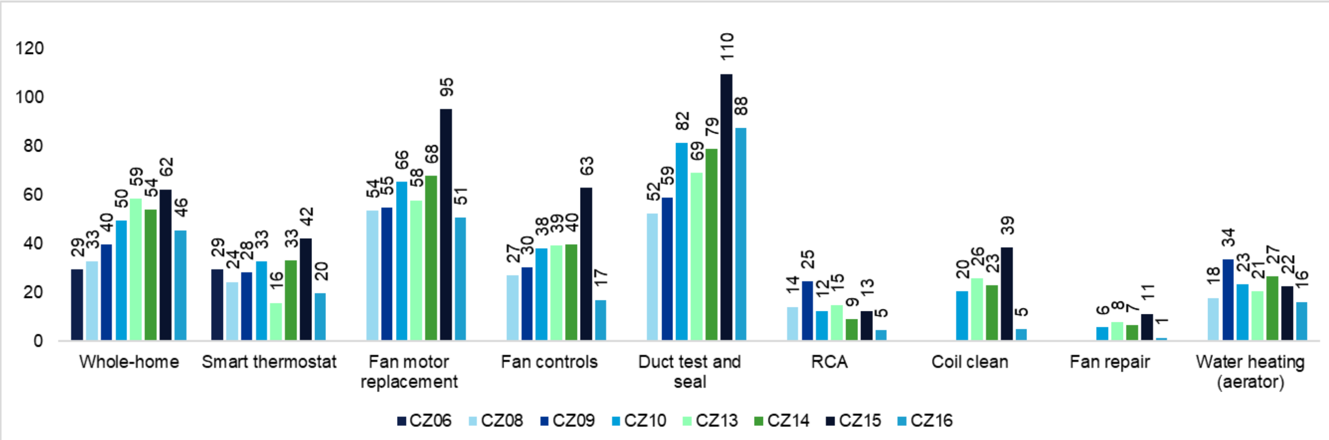
Figure 4-9 provides the PY2021 average measure savings by dwelling type. It also provides smart thermostat savings for single-family homes that received this measure alone and had sufficient data available for the evaluation. As the figure indicates, fan motors and duct test and sealing delivered the highest savings in both dwelling types in PY2021. Smart thermostats installed alone also had higher savings than those installed as part of a bundle in single-family households.

**Figure 4-9. Measure level electric savings, PY2021**



Direct install measure level and whole home savings by climate zone based on the approach above are provided in Figure 4-10. The figure indicates that savings estimates vary by climate zone. The savings generally reflect similar relationships as shown in the simulated engineering estimates such as estimated measure savings being higher in climate zones 14 and 15 than in climate zones 6 and 8.

**Figure 4-10. Measure level electric savings by climate zone, PY2021**




## 4.2.3 Free-ridership and program attribution

We derived NTGRs based on program participant survey responses on free-ridership.[47] The PY2021 NTGRs were 80% or above for most incentivized measures, indicating that the programs influenced the timing, quantity, and efficiency of these installations. Table 4-2 presents a longitudinal summary of NTGRs by measure and shows that PY2021 evaluated NTGRs are consistent with those from prior impact evaluations. For most measures, NTGRs fluctuate by about +/- 5% to 10% from 2018 to 2021.

However, the PY2021 NTGR estimates for some measures indicated a departure from prior estimates. The NTGR estimate for fan controls is one such estimate. Thus, we sought to uncover whether there were any anomalies associated with the scoring methodology for this measure in PY2021, but we did not find any. Like in years past, variability in free-ridership is not unusual. For example, the PY2020 NTGR for duct sealing was lower than in the preceding years. While there was a lower-than-expected attribution for the fan control measure, 50% of the other measure scores increased compared to PY2020 estimates.

In PY2021, the programs seem to have influenced the duct sealing measure the most, likely due to the cost and the scope of work required to seal ducts. We used past evaluated attribution rates to determine the NTGR for refrigerant charge adjustment (RCA) because we did not include questions for this measure in the survey as it was sunset from the DEER (i.e., Database of Energy Efficiency Resources) database. RCA was sunset because of its historically low realization rates and potential to contribute to global warming.

**Table 4-2. Longitudinal summary of NTGR values by program type and measure, PY2018-PY2021**

| Measure | Fuel | NTGR (Net to Gross Ratio) | | | |
|---|---|---|---|---|---|
| | | **PY2018** | **PY2019** | **PY2020** | **PY2021** |
| Smart thermostat | kWh | 89% | 94% | 80% | 83% |
| | kW | | | | |

[47] To assess measure installation decision-making without the programs, we provided participants with estimates of the cost of the installed measures. Appendix I, Section 6.9 provides the table of the cost estimates we used for this purpose.

| Measure | Fuel | NTGR (Net to Gross Ratio) | | | |
|---|---|---|---|---|---|
| | | PY2018 | PY2019 | PY2020 | PY2021 |
| | therm | 91% | 90% | 78% | 83% |
| Fan motor replacement | kWh | 85% | 90% | 89% | 85% |
| | kW | 82% | 91% | 89% | 85% |
| | therm | 87% | 91% | 88% | 86% |
| Fan motor control | kWh | | 88% | 86% | 76% |
| | kW | | 88% | 85% | 76% |
| | therm | | 85% | | |
| Duct test and seal | kWh | 94% | 95% | 79% | 87% |
| | kW | 95% | 96% | 80% | 89% |
| | therm | 95% | 94% | 80% | 91% |
| Showerhead aerator | kWh | | | | 83% |
| | kW | | | | 83% |
| | therm | | | | |
| Faucet aerator | kWh | | | | 80% |
| | kW | | | | 80% |
| | therm | | | | |
| Refrigerant Charge Adjustment | kWh | | 96% | | 91% |
| | kW | | 90% | | 91% |
| | therm | | 90% | | 94% |
| HVAC Indoor Coil Cleaning | kWh | | 94% | | 91% |
| | kW | | 80% | | 91% |
| | therm | | 91% | | 94% |

Since the Res DI programs targeted HTR customers in PY2021, we examined NTGRs by HTR status where we had survey data to support this analysis. We found no statistically significant difference in the NTGR values when we compared measures incentivized by the single-family and mobile home direct install programs for HTR versus non-HTR segments of the participant population.

Figure 4-11 and Figure 4-12 illustrate the PY2021 NTGR / free-ridership estimates by measure and HTR status for the two programs referenced above. Although there appears to be differences between HTR and non-HTR segments, those differences were not statistically significant. We did not have sufficient survey responses to compute NTGR for mobile home fan motor replacements by HTR status and for single-family duct sealing HTR participants. Moreover, the programs did not claim smart thermostat savings for HTR customers, so we did provide NTGR estimates by HTR status for this measure.

Figure 4-11. Free-ridership and program attribution (NTGR) scores by measure and HTR segment, PY2021 Comprehensive Manufactured/Mobile Homes (CMH) Program

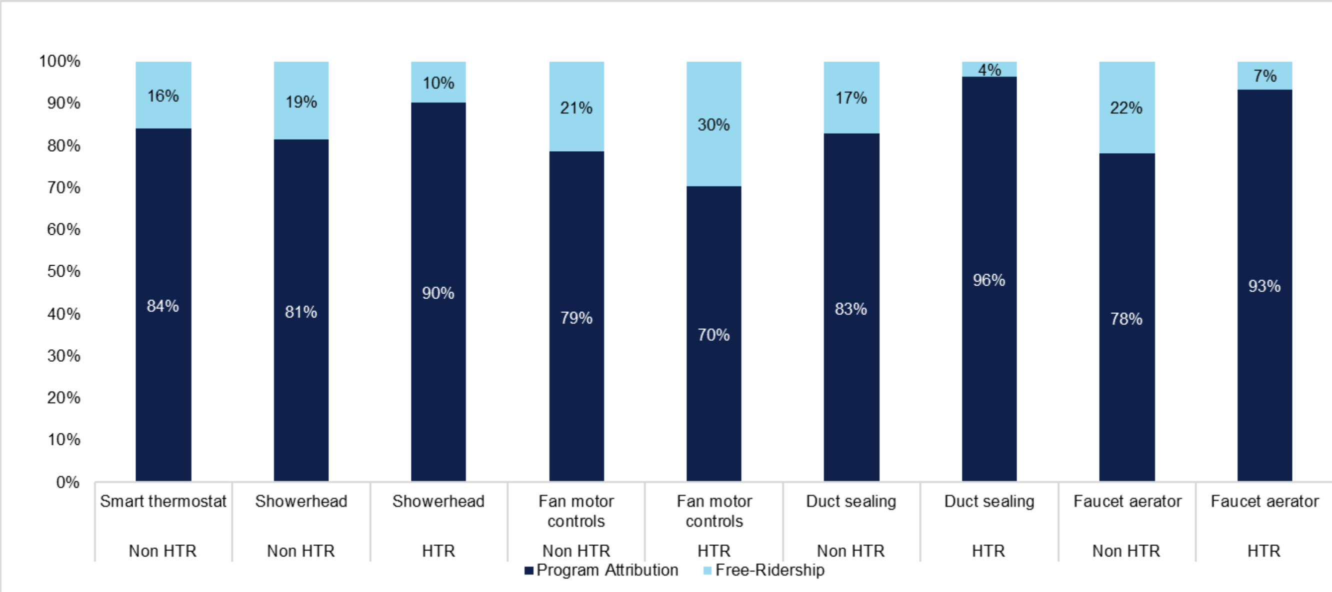
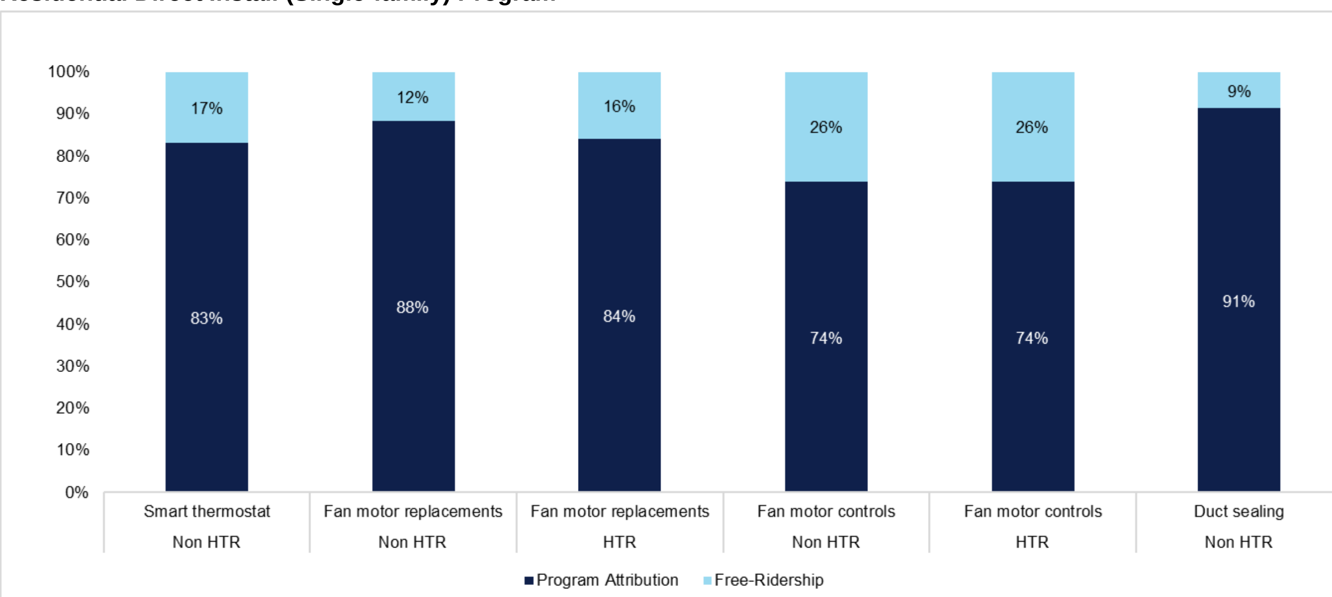



Figure 4-12. Free-ridership and program attribution (NTGR) scores by measure and HTR segment, PY2021 Residential Direct Install (Single-family) Program




## 4.2.4 Total savings

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

### 4.2.4.1 Electric savings

Table 4-3 provides the number of electric savings claims associated with measures installed through Res DI programs, the claimed electric savings (total gross claimed savings), and the achieved savings (total gross evaluated savings). These measures achieved approximately 876 MWh of gross electric savings, which is 10% of gross claimed savings (gross realization rate).[48] Total evaluated gross savings are further adjusted to reflect the portion of savings that are due to program influence using net-to-gross ratios (NTGR). Our evaluation indicates that the Res DI programs caused electric savings of 721 MWh.

**Table 4-3. Total electric savings by measure level**

| Measure | Number of installations | Total gross savings (kWh) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total net evaluated savings (kWh) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Smart thermostats | 12,597 | 2,958,751 | 406,167 | 14% | 90% | 83% | 337,119 |
| Fan motor replacement | 2,099 | 888,857 | 135,245 | 15% | 64% | 85% | 114,958 |
| Fan controls | 5,861 | 1,987,221 | 224,584 | 11% | 69% | 76% | 170,684 |
| Duct testing and sealing | 514 | 100,356 | 48,133 | 48% | 57% | 87% | 41,876 |
| Coil cleaning | 139 | 6,514 | 2,798 | 43% | 58% | 91% | 2,546 |
| Fan repair | 153 | 2,060 | 901 | 44% | 58% | 91% | 820 |
| Refrigerant charge adjustment | 3,901 | 2,472,135 | 51,489 | 2% | 64% | 91% | 46,855 |
| Water heating (aerators) | 2,356 | 220,445 | 6,969 | 3% | 66% | 81% | 5,680 |
| **Total** | **27,620** | **8,636,339** | **876,287** | **10%** | **74%** | **82%** | **720,537** |

Table 4-4 provides the number of households with electric measures expected to deliver demand (kW) savings and the total kW savings claimed for each measure. We evaluated demand savings of households that installed the measures with the claimed savings based on peak demand savings estimates during DEER-defined peak periods. Households with these measures achieved 153.8 of gross kW savings, which is 4% of gross claimed gross kW savings. Total gross kW savings are further adjusted to reflect the portion of savings that can be attributed to program influence. Our evaluation indicated that the direct install programs that delivered measures with claimed demand savings achieved net electric savings of 125.4 kW.

**Table 4-4. Total kW demand savings by measure level**

| Measure | Number of installations | Total gross savings (kW) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total net evaluated savings (kW) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Fan motor replacement | 2,099 | 690.4 | 39.8 | 6% | 64% | 85% | 33.8 |
| Fan motor controls | 5,861 | 816.1 | 68.9 | 8% | 70% | 76% | 52.3 |
| Duct testing and sealing | 514 | 84.7 | 12.7 | 15% | 57% | 89% | 11.3 |
| Coil cleaning | 139 | 6.8 | 0.9 | 13% | 58% | 91% | 0.8 |
| Fan repair | 153 | 2.1 | 0.3 | 13% | 58% | 91% | 0.3 |
| Refrigerant charge adjustment | 3,901 | 2,426.4 | 15.4 | 1% | 63% | 91% | 14.1 |
| Water heating (aerators) | 2,356 | 44.7 | 15.9 | 35% | 66% | 81% | 12.9 |
| **Total** | **15,023** | **4,071.2** | **153.8** | **4%** | **64%** | **82%** | **125.4** |

[48] The electric GRR of PY2020 Res DI programs was higher at 27%, partly reflecting higher GRR from rebate smart thermostats whose claimed savings were closer to estimated savings. Additionally, the difference in the direct install electric GRR between the two program years is related to differences in the measure mix included in the evaluation in PY2021, primarily the inclusion of RCA and water heating measures in the PY2021 evaluation. PY2021 savings per home were lower than in PY2020 at the same time as claimed savings per household were higher in PY2021 than in PY2020.

#### 4.2.4.2 Gas savings

Table 4-5 summarizes the gas savings by measures received through the Res DI programs. These measures achieved 75,316 therms of gross gas savings, which is 48% of gross claimed gas savings. The programs influenced 83% of the achieved savings and caused gas savings of 62,853 therms.

**Table 4-5. Total gas savings by measure level**

| Measure | Number of installations | Total Gross Savings (therms) | | Gross Realization Rate | Claimed NTGR | Evaluated NTGR | Total Net Evaluated Savings (therms) |
|---|---|---|---|---|---|---|---|
| | | Claimed | Evaluated | | | | |
| Smart thermostats | 12,587 | 163,734 | 72,222 | 44% | 90% | 83% | 59,944 |
| Fan motor replacement | 2,099 | -10,655 | 0 | 0% | 70% | 86% | 0 |
| Duct test and sealing | 514 | 5,377 | 3,095 | 58% | 56% | 94% | 2,909 |
| Coil cleaning | 139 | -4 | 0 | 0% | 62% | 94% | 0 |
| Fan repair | 153 | -1 | 0 | 0% | 63% | 91% | 0 |
| Refrigerant charge adjustment (RCA) | 3,901 | -786 | 0 | 0% | 71% | 94% | 0 |
| **Total** | **19,393** | **157,665** | **75,316** | **48%** | **89%** | **83%** | **62,853** |

### 4.2.5 Future program implications

This section discusses the possible causes of the low electric realization rate and the implications for both the PY2021 Res DI and future programs.

#### 4.2.5.1 Low gross realization rate

PY2021 generated a 10% kWh gross realization rate, lower than the 27% gross realization rate reported in the PY2020 evaluation. However, as Figure 4-8 shows, the evaluated savings per measure are similar to those found in both the PY2019 and PY2020 evaluations. Across all three evaluations, claimed savings per unit were substantially higher than the evaluated savings. Clearly, either savings are consistently too low or claimed savings are too high.

Identifying the source or sources of this problem is made more complicated by the multiple and varied mixes of measures installed in each customer's home. It is beyond current methods to disentangle measure savings based entirely on the empirical data. The measure level savings reported here reflect a combination of the engineering-based allocation of savings and household level pre-post differences, positive and negative, being allocated on the basis of the household measure bundle. The regression will adjust measure savings above or below the engineering allocation based on the level of savings in homes with that measure. There are, however, many possible factors that could, in some combination, explain the shortfall in estimated savings. These factors split into possible explanations of low measure savings estimates and possible over-estimates of deemed savings.

##### 4.2.5.1.1 Measure savings considerations

The program is responsible for installing all the measures and doing so in a way that maximizes the likelihood of savings. Whether it is assuring that measures are installed correctly and in use or successfully identifying sub-optimally charged AC systems and restoring them to an optimal level, potential savings cannot occur without quality installation. Because we pursued a billing analysis approach to this evaluation and did not perform on-site visits to validate measure installation for a sample of program households, we are not able to directly validate that measures were installed per the tracking data. Program delivery cannot be ruled out as part of the explanation for the overall low savings. For example, participant experience based on survey results, discussed in section 4.5.3.1, indicate some installation related problems as well as inadequate instruction on operating smart thermostats installed by the programs.

Another common challenge that can undermine measure savings is customer takeback. The perception of increased efficiency and potential for reduced costs can lead some customers to opt to increase their comfort. While non-energy benefits might flow from these actions, the increased heating or cooling may also more than negate the savings that would have occurred had conditions remained otherwise the same.

Individual measures and measures in combinations may also explain some of the shortcomings in savings. Smart thermostats were installed in approximately 50% of homes and represent 34% of claimed savings. Smart thermostats are a largely behavioral measure and, among the measures installed by the program, have the unique potential to have low or even negative savings depending on how customers use them. We can use whole-home savings estimates for mobile homes with and without smart thermostats installed to understand how this is possible.

Overall, mobile homes had a 6% electric realization rate for the package of all direct installed measures (Table 4-6). Comparatively, mobile homes without any smart thermostats generated a per household savings of 213 kWh (a 46% realization rate) while mobile homes that installed only smart thermostats had negative savings of -120 kWh. Mobile homes that installed smart thermostats with other measures had negative savings of -39 kWh.

**Table 4-6. Res DI program electric whole home savings in mobile homes, PY2021**

| Category | Savings claims | Whole-home savings | | | |
|---|---|---|---|---|---|
| | Number of Installations | kWh | Claimed (kWh) per household | Evaluated (kWh) per household | Realization Rate |
| All installations | 5,923 | 1,493,632 | 573 | 34 | 6% |
| Installations without SCT | 1,178 | 250,601 | 459 | 213 | 46% |
| Installations with SCT | 4,745 | 1,243,030 | 1,375 | -39 | -3% |
| Installations with SCTs only | 100 | 29,238 | 370 | -120 | -32% |

Mobile homes represent a relatively small subset of the Res DI programs accounting for approximately 20% of claimed electric savings. The single-family savings estimates do not exhibit similarly dramatic results. The 6% subset of single-family households that installed only a smart thermostat managed a 26% realization rate. Approximately 90% of single-family installations included a smart thermostat and at least one more measure and those households averaged a 10% realization rate, which is the same as those without a smart thermostat.

Previous evaluations have pointed out the possibility that there is at least partial overlap between fan control capabilities of fan controllers and smart thermostats. Even if the overlapping functionality is only a subset of each measure’s savings, the full expected savings for both measures will not be evident and realization rate will be eroded.

More generally, the savings produced by multiple measures seeking to improve the efficiency of the same system will not equal the sum of savings if each measure were installed individually. In the individual measure scenario, each measure produces savings from the same inefficient baseline. With multiple measures, only the first measure installed is measured against that baseline while later measures face the baseline produced by prior measures.

### 4.2.5.1.2 Measure package review

Another possible reason for the realization rate shortfall could be deemed measure package savings estimates that are too high due to inaccurate assumptions about the existing conditions in the home before the measures are installed. To investigate this possibility, we reviewed the deemed measure package assumptions for those measures with the lowest realization rates: RCA, fan motor replacement, and fan motor controls.

- **SWSV006-01 Refrigerant Charge Adjustment, Residential.** RCA is a high contributor to claimed savings. The average RCA savings per installation is high at 693 annual kWh, which is approximately 20% of a typical single-family home's cooling load. The entire direct install bundle of measures saved less than 2% of the typical cooling load requiring a re-examination of the RCA deemed savings estimates and RCA installation methods. The refrigerant charge adjustment measure package savings are based on a laboratory-developed relationship between HVAC performance and refrigerant charge level. Although we believe this relationship to be accurate, the field methods to determine refrigerant charge level (superheat or subcool tests) have high levels of uncertainty documented in the HVAC 5 CPUC-funded laboratory study. The measure package was discontinued (effective in PY2023) because it did not require technicians to repair leaks before adding more refrigerant.

- **SWHC038-03 Brushless Fan Motor Replacement, Residential.** The fan motor replacement measure package savings methodology is straightforward; it uses a building simulation model to determine savings from reducing the HVAC fan power draw. Two sources of uncertainty are the power draw of the existing HVAC fan motor that is replaced during the installation of this higher efficiency brushless fan motor and the run-hours of the HVAC system. The assumption used for the power draw of the existing HVAC fan motor is based on a 23-year-old study of measured fan motor power draw. The low realization rate indicates a new study of existing fan power draw is needed. Simulation models with "right-sized" equipment will tend to overestimate fan savings because of longer run hours compared to real systems that tend to be oversized. The model could be corrected by sizing the equipment in accordance with AC capacity data collected through the Statewide Residential Quality Maintenance Program.
- **SWHC029-03 Fan Controller for Air Conditioner, Residential.** The HVAC fan control savings are based on a single study from 2012 that measured one three-ton air conditioner in one set of indoor/outdoor conditions with three-part load scenarios. The uncertainty in these measurements is as high as or greater than the savings themselves. This set of measurements is extrapolated to the entire cooling season using a simulation model (in each climate zone) to determine the part load ratio in each hour. If the models that were used have oversized HVAC systems there will be more part load run hours and the savings will be over-estimated. The low realization rate for this measure in multiple evaluation cycles and the high uncertainty in the deemed savings methodology indicate the need for an updated laboratory or field study of fan controllers.
- **SWWH001-02 Faucet Aerator, Residential.** The savings in the measure package are based on assumptions of lavatory and kitchen faucet flow rate, water temperature, and water heater efficiency. Errors in these assumptions such as flow rate that is too high, water temperature that is too high, or water heater efficiency that is too low could lead to overstated measure package savings estimates.

#### 4.2.5.2 Implications for future programs

Low RCA realization rates in this PY2021 evaluation corroborate the PY2019 evaluation study that also found low realization rates for RCA. In previous evaluations, we had theorized that low realization rates for this measure were driven by claims for small refrigerant charge adjustments that may underperform due to the uncertainty of the superheat test. In this evaluation, only 13% of the claims were for medium or small adjustments. This evaluation shows that even substantial refrigerant charge adjustments do not have savings realized at the meter since 87% of the claims accounting for 96% of the claimed RCA kWh savings were for refrigerant charge measures with a 16% adjustment to the rated refrigerant charge level. Programs should discontinue installation of the RCA measure.

Programs installing the fan motor replacement measure should consider collecting existing fan power draw data to improve the assumptions used in the building simulation model so that more accurate deemed energy savings values can be developed in the measure package.

Programs installing the fan controller measure should verify that its functionality does not overlap with that of the existing HVAC system or that of an existing (or installed) smart thermostat.

# 4.3 Savings shapes

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

The multiple measure installations that made estimating annual impacts difficult also pose a challenge for estimating hourly savings shapes. Rather than proportionally distributing whole home savings shapes to individual measures, we provide savings shapes that rely on the subset of customers who only installed smart thermostats, customers who only performed duct sealing, and customers that installed any of the other measures without smart thermostats.

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

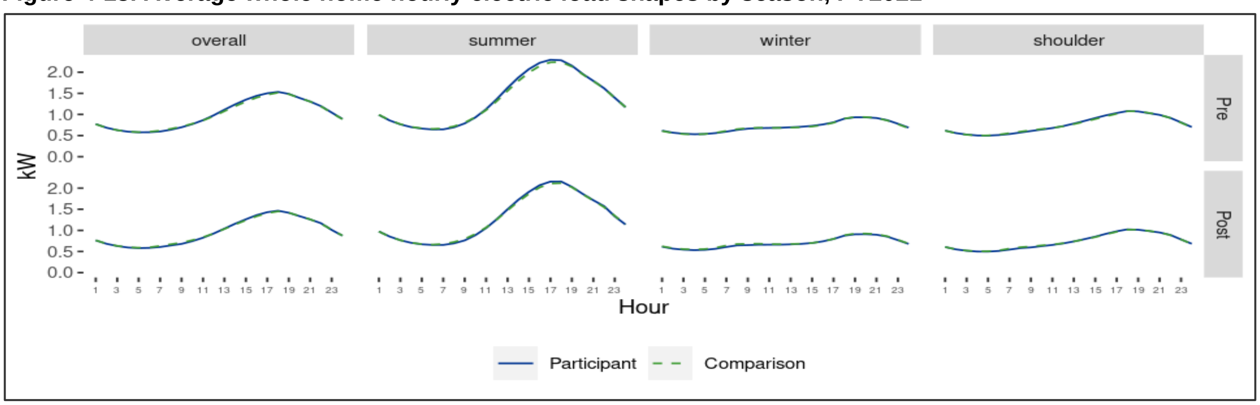
## 4.3.1 Whole home hourly load shapes

Figure 4-13 provides weather normalized average hourly electric load shapes for households that installed residential HVAC measures under direct install programs. The plots include shapes for both treatment (solid line) and comparison group (dashed line) households in each panel, with separate rows for pre- and post-installation periods.

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

The pre-installation average hourly load shapes indicate that participants and comparison group households had similar consumption except during the ramp period to the summer peak when participant consumption was slightly greater than comparison participants. That subtle but evident separation reduces in the post period indicating peak period reductions by the participants.[49]

**Figure 4-13. Average whole home hourly electric load shapes by season, PY2021**




[49] This is a good example of why the difference in difference approach is essential.

## 4.3.2 Hourly savings shapes

We calculated DID of weather normalized hourly load to estimate hourly whole home savings. We produced savings shapes for all dwelling types that installed the direct install residential HVAC measures based on these estimates. The panels in Figure 4-14 provide the average hourly savings by season. These savings shapes represent a combination of all direct install measures. The hours in all figures below are for the hour ending; for example, 15 represents the hour that ends at 3 p.m.

**Figure 4-14. Direct install whole home average hourly savings by season for all housing types, PY2021**

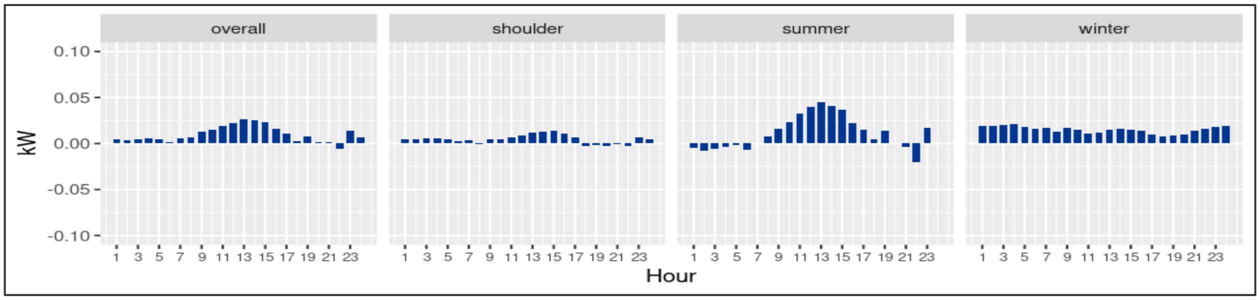



Figure 4-15 provides the savings shapes for homes that installed measures other than smart thermostats, consisting of measures such as fan motor replacements and duct sealing. The figure indicates that these measures deliver most of their summer savings during afternoon hours, which include the peak demand period of 4 p.m. to 9 p.m., demonstrating their potential to reduce demand during summer periods of grid stress. These measures make the HVAC system more efficient thus producing energy savings and demand reduction across all cooling hours proportional to HVAC system use. The measures deliver most of their winter savings during the early morning hours and, to some extent, in the late afternoon hours.

**Figure 4-15. Direct install average hourly savings for homes without smart thermostat installations**

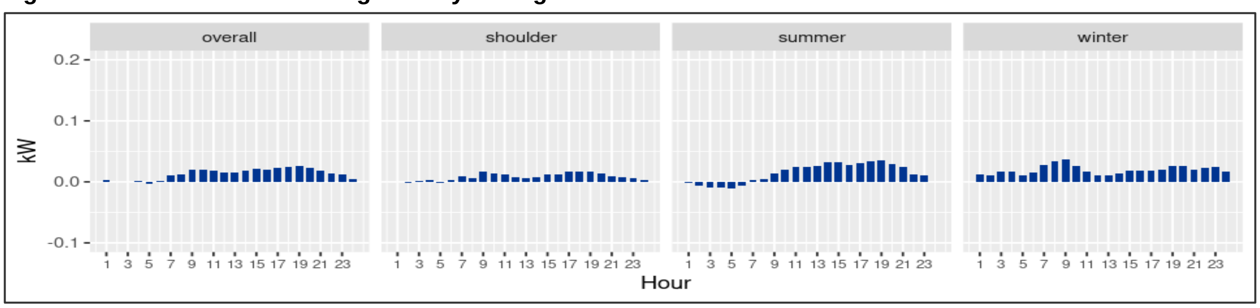



Figure 4-16 provides savings shapes for homes that only installed smart thermostats. This figure indicates that the measure delivered most of its savings during the early afternoon hours of the summer. Savings are highest when most people are more likely to be out of the home and the technology can adjust the thermostat's setpoints to reduce electricity consumption. We identified a similar savings shape for this measure in our PY2019 evaluation. Our PY2020 evaluation, on the other hand, indicated the absence of such savings during the afternoon hours, most probably because most participants were home due to the COVID pandemic. During the summer of 2020, the optimization feature of the thermostat may have had fewer opportunities for savings through summer setbacks.

Figure 4-16. Direct install average hourly savings for homes with only smart thermostat installations

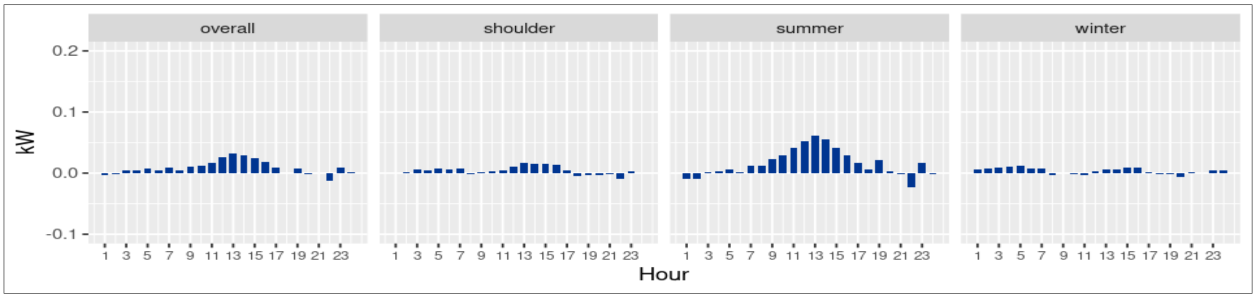



Figure 4-17 shows the hourly savings for homes that only received duct testing and sealing services. Similar to HVAC measures shown in Figure 4-15, savings for homes with this upgrade primarily occurred across all hours with HVAC load, with the highest savings taking place during the late afternoon hours. While these savings shapes are based on data from 45 homes that received only this service, they provide directional evidence of the notable contributions to peak demand reductions that this measure can offer.

Figure 4-17. Direct install average hourly savings for homes with only duct testing and sealing

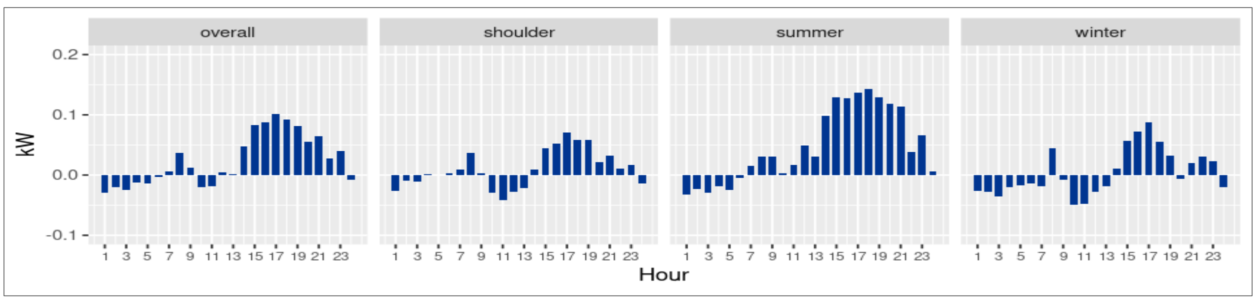



Figure 4-18 and Figure 4-19 provide average hourly savings shapes by season for single-family and mobile homes that received the direct install measures. Both savings shapes closely mirror the same shapes generated by the smart thermostat-only homes (Figure 4-16).

Figure 4-18. Direct install whole home average hourly savings by season for single-family homes, PY2021

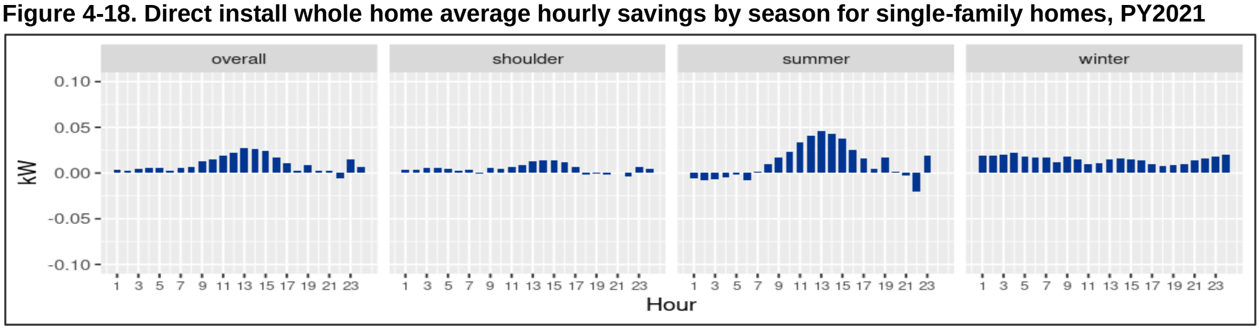


**Figure 4-19. Direct install whole home average hourly savings by season for mobile homes, PY2021**


### 4.3.3 DEER peak period hourly load and savings shapes

We used TMY (CZ2022) data to determine the peak period based on the DEER definition and examined hourly load and savings shapes during that period.[50] Figure 4-20 summarizes the hourly load reduction on those days for participants with direct install HVAC measures. The DEER-defined peak period includes the five hours between 4 p.m. (hour ending 17) and 9 p.m. (hour ending 21) and occurs later in the day than the maximum load reduction from these measures.

**Figure 4-20. DEER peak days average load savings shapes for Res DI installations, PY2021**

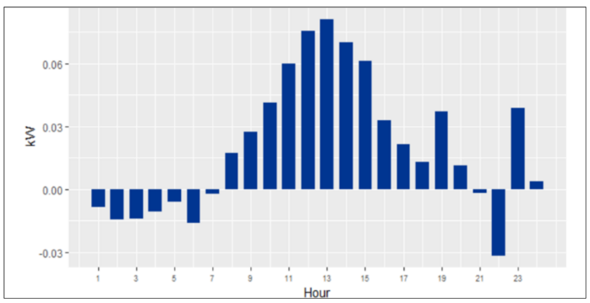



Table 4-7 summarizes the average hourly load reduction during the 4 p.m. to 9 p.m. period. The table summarizes results from whole home load reduction across all participants and by certain installation activities. Overall, participants saved 0.02 kW during the peak period, resulting in a 0.5% reduction in peak load. Participants who only installed smart thermostats saved about 0.2% of peak load, while participants who received measures other than smart thermostats saved 1.5% of peak load. The 45 homes that only received duct testing and sealing services reduced about 8% of their peak load.

**Table 4-7. DEER peak period average hourly baseline and load reductions for Res DI**

| Participation segment | 4 p.m. - 9 p.m. | | | |
|---|---|---|---|---|
| | Household counts | Savings (kW) | Baseline (kW) | Percent savings |
| **Overall** | 7,543 | 0.02 | 3.1 | 0.5% |
| **Smart thermostat only** | 2,635 | 0.01 | 3.2 | 0.2% |
| **No smart thermostat** | 1,340 | 0.04 | 2.9 | 1.5% |
| **Duct testing and sealing only** | 45 | 0.22 | 2.9 | 7.6% |

## 4.4 Onsite solar generation and energy consumption

The onsite solar generation analysis was designed to assess the feasibility of using predictions of solar generation based on installation characteristics and actual solar irradiance to reconstitute full consumption data from net metered consumption data. The output of this analysis was not included in the impact results produced above. In this section, we provide

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

preliminary results from analysis of estimates of onsite solar production and total energy consumption of customers with onsite photovoltaic (PV) solar.

### 4.4.1 Site selection

For the Residential Direct Install program, the evaluation team requested solar system characteristics for 15,554 participants that have solar PV systems. Ultimately, we ran simulations for 9,450 of these customers. Table 4-8 shows the disposition of these sites and why they were excluded from the analysis.

**Table 4-8. Disposition of Res DI participants with solar systems**

| Disposition | Number of premises |
|---|---|
| Direct Install participants that have solar energy | **15,554** |
| - Premises missing system information | 133 |
| - Premises missing latitude and longitude | 135 |
| - Premises farther than 50 kilometers from the coordinates for which solar data was acquired | 266 |
| - Premises that underwent PV system expansions during the test period | 1,280 |
| - Premises that underwent PV system installation during the test period | 4,290 |
| **Premises available for solar simulation** | **9,450** |

The resulting simulations were further screened based on:

- The ratio of maximum hourly kW to installed capacity. An acceptable ratio is between 0.9 and 1.0. About 5% of the sites did not pass this screen. Ideally, we would have used expected annual kWh to annual simulated kWh, but the expected annual kWh was null for all records
- Installed capacity over 20 kW. A few sites had systems with high installed capacity. Several of these were confirmed to correspond to virtual net metered (VNEM) sites. For this test, all sites over 20 kW were removed. This removes many VNEM sites, and probably also some large residential sites. In future uses of this approach, the NEM-VNEM status of the sites will be confirmed with billing records.
- Negative whole house energy use. For whole house energy use, a negative hourly value means that the solar simulation overestimated solar production for that hour.

At the hourly level, it will be near-impossible for the solar simulation model to be perfect. Less-than-perfect simulations are likely to result from factors that are not captured accurately in the available system data. For example, if the system has more than one tilt or azimuth, it is common that only the prevalent combination is entered into the system data, or that the shading assumptions are not right for some of the systems.

Most importantly, if these negative values are not substantial, they do not interfere with our ability to estimate energy savings, although they could interfere with our ability to estimate demand savings.

At the daily level, over 99% of the sites have good estimates. The hourly over- and under-estimation occurring for some hours does not overwhelm the daily estimates. This means that, while the hourly estimates for some of these sites may not be accurate to pinpoint demand savings on very specific days and hours, the resulting estimates support weather normalization, which is a critical step in EE savings estimation.

**Table 4-9. Disposition of solar system simulations**

| Disposition | Number of premises |
|---|---|
| Number of premises that underwent solar simulations | **9,450** |
| - Solar simulation software does not handle systems less than 1 kW | 10 |
| - Sites with missing or incomplete AMI data | 11 |
| - Sites with installed capacity > 20 kW | 25 |
| - Sites with ratio of installed capacity to estimated max kW not within 10% | 524 |
| - Negative whole house energy use | 1,643 |
| **Premises available for analysis** | **7,237** |

### 4.4.2 Solar simulations and whole house estimates

In this section, we provide results from the simulation used to generate solar production along with NEM AMI and estimated whole house electricity consumption based on data aggregated to daily kWh level because the hourly detail produces very dense graphics that are difficult to view.

Figure 4-21 is for a premise with "likely good" estimates of whole house energy use. The energy production estimate is within the expected system capacity reported to the utility, and there are no negative whole house energy use estimates.

**Figure 4-21. Example of a "likely good" whole house electricity use estimate**

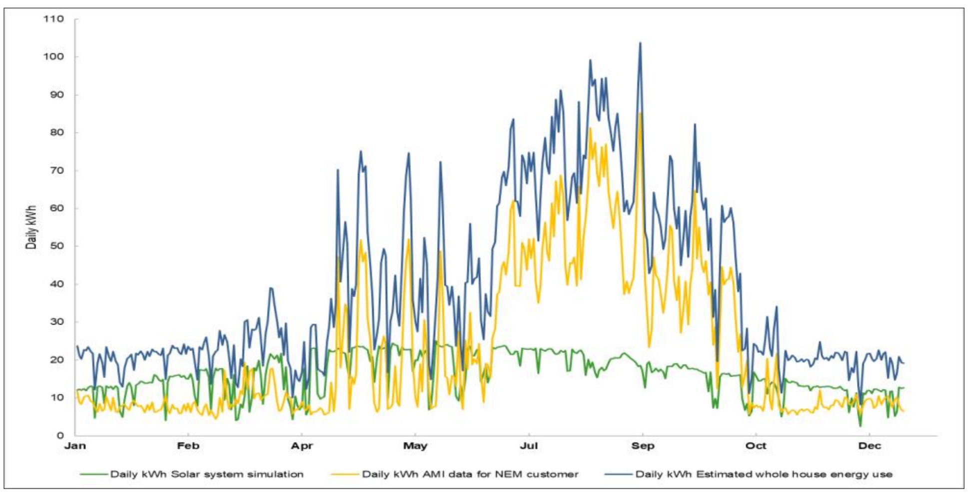
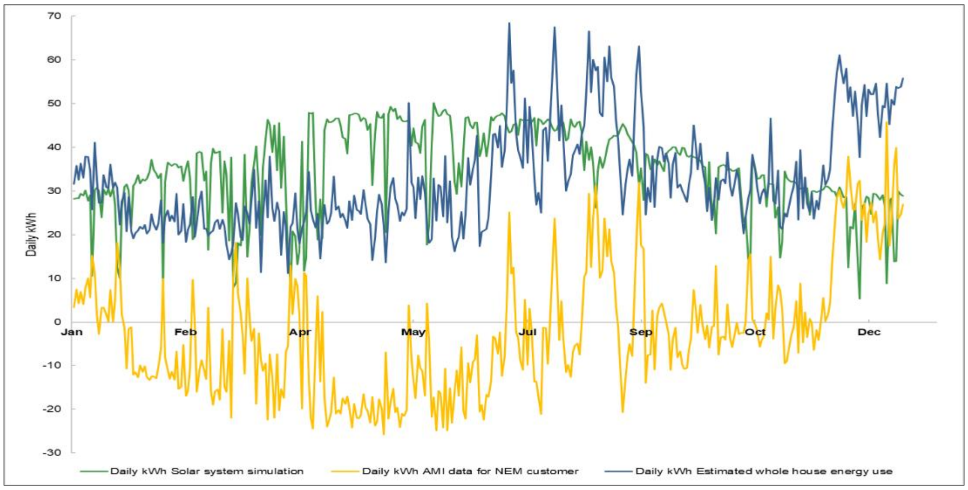



Figure 4-22 is also for a premise with acceptable estimates of whole house energy use, but one where the NEM AMI data indicates that this system is a year-round net producer. This system produces more energy than the house requires most days of the year and is thus "oversized" for the needs of the house.

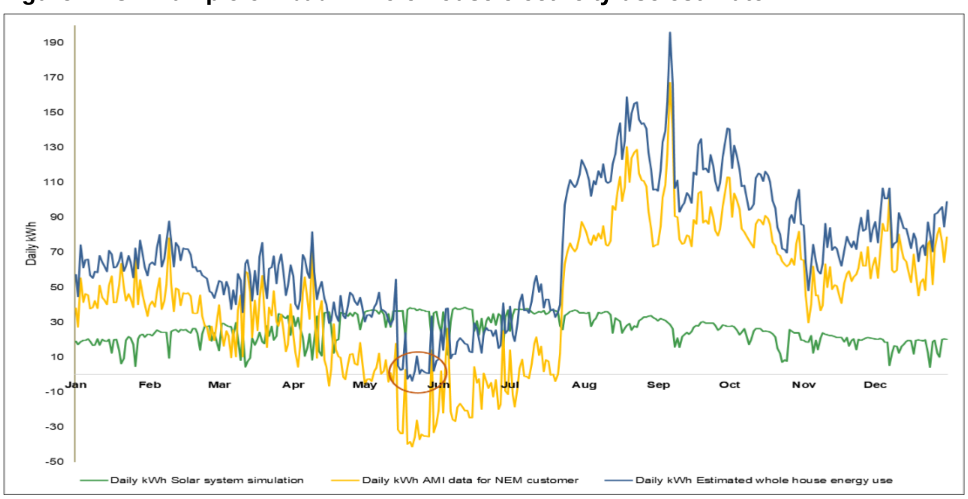
**Figure 4-22. Example of a "likely good" whole house electricity use estimate for an oversized solar system**




While there is some uncertainty around "likely good" estimates, "bad" estimates identified by hours when the site is estimated to use negative energy, a physical impossibility, are unambiguous. The second and third graphs are for sites with negative whole house energy use estimates.

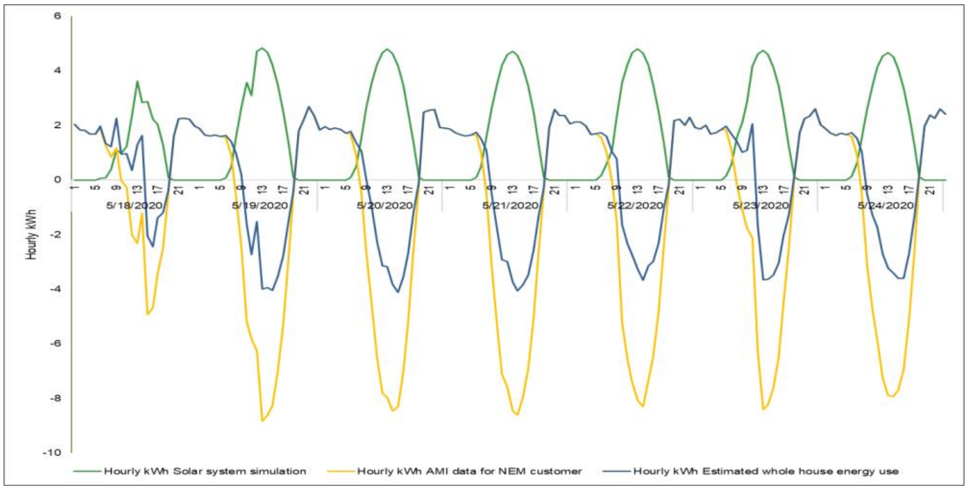
Figure 4-23 displays net metered daily kWh (the yellow line – the only observed data), estimated solar production (the green line), and estimated whole house energy use (resulting from combining the observed net kWh and the solar simulation). This figure shows that there are two days of the year (in the red circle) when the whole house energy use is estimated to be negative – a physical impossibility.

**Figure 4-23. Example of "bad" whole house electricity use estimate**




However, the analysis of hourly data shows that the solar simulation is underestimating actual solar production. Figure 4-24 shows the hourly details for the week when the estimated daily whole house energy use is negative.

**Figure 4-24. Hourly detail for the "bad" whole house electricity use estimate**



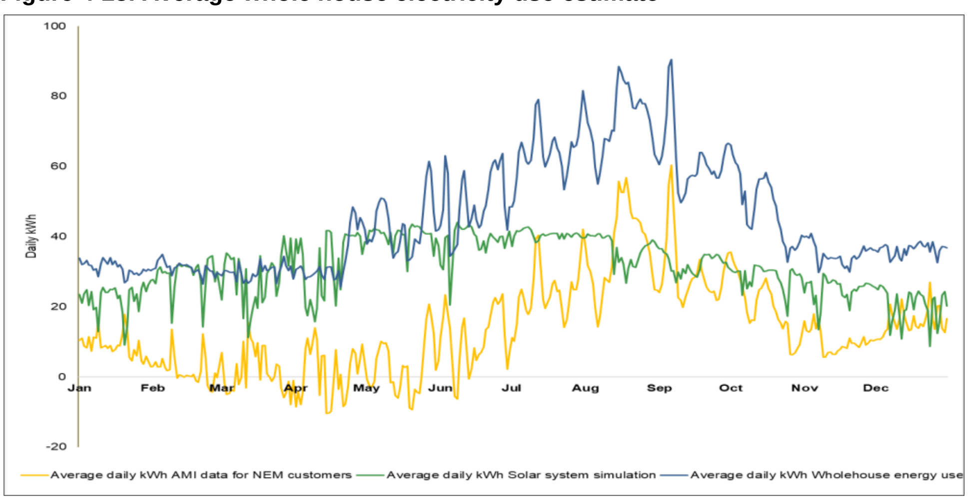

### 4.4.3 Average whole house estimates

The evaluation team averaged the AMI data and the solar system and whole house estimates for the 7,237 premises that are "likely good". These averages are displayed in Figure 4-25.

These estimates are not yet ready for use in program impact estimation, for the following reasons:

- These estimates are not weighted. The evaluation team has yet to determine whether the individual premises that are "likely good" will require statistical weights. It is highly likely that they will.
- As described in the preceding subsections, the screening criteria need to be refined. For example, VNEM customers must be clearly identified.

**Figure 4-25. Average whole house electricity use estimate**




## 4.5 Program performance

This section provides DNV's assessment of the performance of the Res DI programs, including the programs' design, marketing and outreach activities, and delivery. It also provides an assessment of the equitable delivery of the programs' energy efficiency services.

## 4.5.1 Program design

According to the California Evaluation Framework,[51] well-designed EE programs articulate the barriers they intend to address and strategies to overcome these barriers. They also provide a well-defined program theory that indicates the market sector the programs target and the interventions and services that they offer.

The Res DI PIPs indicate that SCE designed the manufactured home program to address income barriers faced by mobile home residents and the lack of master-metered mobile home residents' full visibility into their energy consumption.[52] The PIPs also indicate that the single-family residential direct install program addresses electric system constraints and energy hardships faced by single-family participants.[53] The programs' strategies to handle these barriers include the direct installation of no-cost HVAC and water heating energy efficiency measures.

The PIPs also indicate that the PY2021 Res DI programs targeted HTR customers, and customers that are in disadvantaged communities (DACs), rural and tribal areas, public safety power shut off (PSPS), wildfire zones, and emergency load reduction program hot climate zones (9, 10, 13, 14, and 15).

## 4.5.2 Program outreach and marketing

Synergy served as the third-party program implementer and installation contractor for the Res DI programs. It also provided a downstream marketing channel to help recruit customers with outreach strategies such as SCE email campaigns, Synergy web marketing, assigning liaisons to help build relationships with park managers in hard-to-reach (HTR) areas, and canvassing neighborhoods. As part of door-to-door canvassing, program representatives introduced customers to the program and scheduled in-home assessments. The multipronged recruitment strategy aligned with the goals of reaching the specific customer segments the programs targeted.

Program participant responses to a survey question about how they first heard of SCE's Res DI programs reflect Synergy's multipronged approach. Table 4-10 indicates that respondents cited several sources for program awareness. It shows that most participants learned about the programs through direct outreach approaches, with more than 1 in 4 participants learning about the program through door-to-door canvassing.

**Table 4-10. First means of learning about Res DI programs, PY2021**

| Source | Participants (n=1,089) |
|---|---|
| Flyer left on the door or canvasser | 27% |
| Word of mouth (neighbor or property manager, etc.) | 19% |
| Phone call or email | 16% |
| SCE utility bill insert | 10% |
| Previous program participation | 7% |
| Ad or promotion on a website (e.g., social media) | 6% |
| SCE website | 6% |
| Don't know | 10% |

[51] CALMAC, "The California Evaluation Framework," calmac.org, June 2004, https://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf

[52] Southern California Edison, "Customer Energy Efficiency and Solar Division Program Implementation Plans," cedars.sound-data.com, 2013-2014, https://cedars.sound-data.com/documents/download/908/main/

[53] South California Edison, "Residential Direct Install Program Implementation Plan," cedars.sound-data.com, 10/1/2018, https://cedars.sound-data.com/documents/download/1303/main/

## 4.5.3 Program delivery

As part of the verification of measure installation, participants were asked if program measures are still in place and operational. Table 4-11 summarizes the share of participants who reported that the respective measure was in place and operational. While water saving measures were more likely than other measures to be no longer in place, the sample sizes on which these responses are based were quite small. Additionally, open-ended responses to other questions (related to satisfaction) revealed that, often if measures were no longer installed, they were removed due to improper installation, faulty features, or general dissatisfaction with the measure.

**Table 4-11. Participant self-reported measures still in place and operational**

| Measure | N | Participants |
|---|---|---|
| HVAC duct test and seal | 26 | 96% |
| Smart thermostat | 944 | 94% |
| HVAC indoor fan motor controller | 67 | 94% |
| HVAC indoor fan motor replacement | 55 | 94% |
| Showerhead | 16 | 86% |
| Faucet aerator | 18 | 81% |

### 4.5.3.1 Participant experience

We assessed participant experience based on a range of interactions with the programs, including satisfaction, perceptions of program benefits, barriers to participation, the information programs provided, and factors that influenced participants' decisions to participate. Satisfaction with the programs and many of their elements were sound, yet satisfaction with energy savings and non-energy impacts was not as high as we might expect. Below, we explore the evidence that this *may* be due to inadequate end-user education or program measures that may not function correctly.

**Program satisfaction.** Participants rated aspects of their satisfaction with the programs using a 5-point scale where 1 is *Not at all satisfied* and 5 is *Extremely satisfied*.

- As Table 4-12 summarizes, most participants were satisfied – providing ratings of 4 or 5 – with the overall program experience, experience with the installation contractor, and the upgrades and maintenance they received. These results indicate that participants had favorable experiences, and the technology offerings and processes used to deliver them worked well.
- While still the majority, slightly fewer than three-quarters of participants, were satisfied with the information and education provided by the program. It is unclear if dissatisfaction is with the breadth or quality of educational materials, or the installation contractors' communication tactics around them.
- While majorities expressed satisfaction with energy savings and non-energy impacts, it is noteworthy that more than one-quarter of participants are dissatisfied or not satisfied (separately) with either of these.

**Table 4-12. Participant satisfaction with Res DI program elements, PY2021**

| Program element | n | Participants satisfied (rating of 4 or 5) |
|---|---|---|
| Overall program experience | 854 | 87% |
| Experience with installation contractor Synergy | 843 | 85% |
| Equipment upgrades and maintenance | 808 | 84% |
| Information and education provided by program | 833 | 74% |
| Energy savings and cost reduction | 818 | 71% |
| Non-energy impacts (e.g., increased comfort due to HVAC) | 730 | 70% |

Respondents used a scale from 1 to 5 where 1 is *Not at all satisfied* and 5 is *Extremely satisfied.*

The survey captured open-ended responses to “experience with the installation contractor” and “equipment upgrades and maintenance” if they rated below a four on the 5-point scale. The survey contained between 50 to 60 open ended comments for each question. These identified minor to significant challenges with the program that, in some cases, ended up costing the customer money out of pocket to correct. Upon review of the open-ended responses, we found 21% cited a lack of education on how to use the thermostat correctly, 35% had poor installation and operational issues, another 17% cited poor installations, 13% expressed disappointment with their energy bills, and the remaining 30% were split near evenly between poor scheduling, poor follow up, and unmet expectations on the program scope of services. We selected a series of verbatim comments to illustrate issues customers faced (Table 4-13).

**Table 4-13. Reasons for customer dissatisfaction with the programs**

| Low satisfaction reasons | Verbatim responses |
|---|---|
| **Lack of education on thermostat** | *“No training on the new thermostat. “*<br><br>*“Didn't educate me very well on the thermostat itself and how to operate it.”*<br><br>*“Not very informative, installers lacked knowledge for installing the equipment”.*<br><br>*“The technician just changed the thermostat and said nothing about it. I learned how to use it by playing with the options.”.*<br><br>*The installer didn't hook my thermostat to WI-FI and didn't tell me I needed to do it. I called Honeywell when I couldn't change the time and they walked me through the procedure.*<br><br>*“My previous smart thermostat (Nest) was better and easier. I saved a lot more money. The new shower heads didn't work well, and I had to replace one within a month of installation.”*<br><br>*“I had issues with operating the thermostat. I prefer my previous thermostat which was simpler to use.*<br><br>*“The Honeywell thermostat was not reliable. Turned on and off randomly. I replaced myself it with a simple Nest model.”* |
| **Lack of energy savings** | *“Dissatisfaction isn't with the installer. I thought I was going to save a lot of money and I didn't.”*<br><br>*“I feel like my bill has gone up in price since getting the thermostat installed.”*<br><br>*“I didn’t have any cost reduction, actually my bills were higher.”* |

| Low satisfaction reasons | Verbatim responses |
|---|---|
| **Poor installation and operational issues** | *"Incorrect installation of thermostat led to A/C malfunction. I had to have A/C technician come out and repair the A/C unit."*<br><br>*"Repairs due to the malfunction of the thermostat were costly."*<br><br>*"I have the T9 Honeywell model thermostat; it worked ok after the installation, but after that, it would not function for extended periods; I tried contacting the provider but didn't get the issue resolved, I had an Eco with a large screen before this one was installed with Vivint & it worked well."*<br><br>*"Installer was not competent in his work. Knowledge was very minimal. The tasks I was told would be done were not and the few that were done were done slowly and poorly. The technician seemed to be running behind and was in a hurry. Some HVAC registers were not reinstalled correctly with less screws than they originally had. Had I not caught this after the tech left would have had one or few registers fall possibly hurting someone or causing damage in the home."*<br><br>*"When the installer went into the attic to check the ducts, some of the vents stopped working. I do not know what they did in the attic, but we do not have heating or cooling in at least one room in the house. We did not discover this until the crew left and when we called them, they said we had to call an AC expert for that. They denied that it was their doing."*<br><br>*Nothing has worked completely right since the installation and then the blower doesn't kick on when the air conditioner unit does and now the air conditioner unit isn't kicking on at all.* |
| **Unmet expectations for scope of project** | *"They weren't able to fix everything they talked about."*<br><br>*I received none of the program's information. I was told someone would come and check all the weather stripping; it has not happened."*<br><br>*"I was told they would come back out to do the duct test and seal and then never heard back and couldn't get in contact with anybody. This still needs to be done to increase efficiency."*<br><br>*"I was under the impression they also helped with weather stripping."* |
| **Poor communication /scheduling or follow up** | *"We weren't given any information about why the thermostat was installed until we asked. We didn't know our thermostats would be controlled. We have no problem with that. It would just have been helpful information."*<br><br>*"The lack of communication with the homeowner, and the scheduling of the work to be done. The contractor didn't explain all paperwork would be electronic. I should have had the opportunity to read about the benefits, and the pros and cons of the program."*<br><br>*"Nobody ever showed up from SCE, and after several calls to Synergy, they closed our case. Then they said they were going to re-open the case and a month later they told us that they could not re-open the case. We're so frustrated and don't want to deal with these unresponsive people!"* |

**Self-reported benefits from the program.** The benefits participants experienced following program participation generally correspond with their reported levels of satisfaction. Table 4-14 shows the frequency with which Res DI participants observed the benefits we asked about.

A primary program goal is to alleviate the energy burden for customers yet only 39% self-reported "energy savings" when asked, "Have you experienced one or more of the following benefits from participating in this direct install program?"

Only two-fifths of participants reported energy savings. The programs delivered only a fraction of the savings that they claimed (Section 4.2), so the responses here align with the performance of the program. The lower satisfaction ratings with energy savings and non-energy impacts underscore the value of identifying what may be hindering savings. Here are some hypotheses to explore:

- Measures may not be delivering properly, perhaps, due to being operated incorrectly by end users, installed improperly, or having faulty features.
- Participants may need more education. Less than one-half of participants recalled being provided tips on how to save energy with the installed equipment. Moreover, a much smaller share remembered receiving tips on how to save energy unrelated to the installed equipment (details below). However, during the in-depth interview, the PA/implementer stated that the programs strive to achieve deeper savings beyond installing program measures; they described using a "playbook" to provide customers with information about things they can do in their homes to reduce energy use.

**Table 4-14. Participant self-reported benefit from Res DI program, PY2021**

| Reported benefit | Participants (n=1,089) |
|---|---|
| Energy savings | 39% |
| Increased comfort | 28% |
| Indoor air quality improvements | 15% |
| Decreased operations and maintenance costs | 15% |
| Reduced noise | 7% |
| Other | 3% |
| *None* | *22%* |

Multiple responses permitted

**Information provided.** We asked customers about the types of information the programs provided them to understand the connection between their self-reported benefits and satisfaction ratings. As shown in Table 4-15, about half of participants recalled the installers providing tips on how to save energy with installed equipment and about 1 in 5 recalled receiving general energy saving tips. Only one-quarter of participants said that the installer recommended other SCE programs.

**Table 4-15. Participant recollections of materials provided by installers, PY2021**

| Information provided | Participants (n=1,089) |
|---|---|
| Provided tips on how to save energy with the installed equipment | 47% |
| Recommended SCE energy efficiency or demand response programs | 25% |
| Provided tips on how to save energy unrelated to the installed equipment | 19% |
| None | 11% |
| Don't recall | 20% |

Multiple responses permitted

**Perceptions of program goals.** Most participants perceived that SCE offers the Res DI programs to help customers reduce energy use. By asking customers to identify the reasons that SCE offers this program for customers like them, we can assess the effectiveness and clarity of program communication and participants' attitudes.

Most commonly, participants selected “To help me save energy” as the reason SCE offers the Res DI programs. They also speculated that SCE offers the programs to help customers save money, improve their heating and cooling systems, save the environment, and avoid blackouts. Given these findings, the programs appear to be communicating their purposes to customers effectively.

**Table 4-16. Participant perception of the purpose of the Res DI programs, PY2021**

| Perceived program purpose | Participants (n=1,089) |
|---|---|
| **Customer support** | |
| Help me save energy | 67% |
| Help me save money | 42% |
| Improve the performance of the home heating and cooling system | 40% |
| Help avoid rolling blackouts | 38% |
| Improve the health, safety, and the comfort of my home | 27% |
| **Environment** | |
| Help save the environment | 40% |
| Help avoid using power plants that produce higher carbon emissions | 22% |
| **Participation levels** | |
| Communicate and encourage participation in other energy saving programs | 30% |
| Reward me for this and other past participation in SCE programs | 17% |
| *Don’t know* | *4%* |

Multiple responses permitted

**Drivers to participation.** While the factors influencing customers’ decisions to participate in the programs varied, most often, they enrolled in the program simply because it was free (Table 4-17). They also pointed to their desire to reduce their energy bills and their attraction to the “ease of use” of program measures.

**Table 4-17. Influential factors in customer decision to participate in the Res DI program, PY2021**

| Influential factor | Participants (n=1,089) |
|---|---|
| SCE program was free/ no cost to me | 71% |
| Reduced my energy bills | 32% |
| Ease of use (e.g., smart thermostat) | 22% |
| Improve occupant comfort and safety, reduce noise, convenience | 14% |
| Reduce carbon emissions / climate change / good for the environment | 13% |
| Family / friend / neighbor recommendation | 11% |
| Equipment needed maintenance or reaching end of useful life | 8% |
| HVAC contractor recommendation | 2% |
| Property manager requested | 2% |
| Other | 2% |

Multiple responses permitted

**Barriers to participation.** Eight percent of participants reported that they faced a barrier or challenge when participating in the Res DI program (Table 4-18).

Sixty-one participants went on to describe their issues. Most often, they (19 respondents) cited problems with the measures malfunctioning and/or needing to be replaced entirely. Some respondents added that getting post-install support from the program – when it came to fixing faulty measures or programming thermostats – was impossible. However, during our in-depth interview, we learned that "Synergy wants a customer for life," provides repair and replacement where possible, and a no-hassle 1-year labor and 3-year materials warranty which guards against manufacturer defects. Other issues included scheduling delays and communication with Synergy, disappointment with the variety of measures offered, and limited education around using the thermostats. Though anecdotal, these responses support our hypotheses that a combination of participant education and problems with measure use and function could be to blame for low satisfaction with energy savings.

**Table 4-18. Participant reports of challenges or barriers when participating, PY2021**

| Response | Participants (n=898) |
|---|---|
| Did not experience challenges or barriers | 78% |
| Experienced challenges or barriers | 8% |
| Don't recall | 15% |

Values sum to greater than 100% due to rounding.

#### 4.5.3.2 Integrated demand side management

One of SCE's objectives is to build a virtual powerplant[54] using demand response as a resource. In March of 2021, the Residential Direct Install Program initiated integrated demand side management by leveraging one of SCE's Demand Response programs called the Smart Energy Program to contribute to this objective.[55] The program educated participants who received smart thermostats through the energy efficiency-funded Res DI program about the benefits of demand response and enrolled qualifying customers. The survey included a sequence of questions on awareness, the extent of cross-promotion of the Smart Energy program, and barriers to participation. A similar set of questions were asked of non-participants. Results are shown in Table 4-19.

- Roughly one-half of participants were educated and offered to enroll in the SCE Smart Energy program.[56] Three-quarters of those participants then agreed to enroll. A significantly smaller share of non-participants was aware of the SCE Smart Energy program and/or enrolled in the Smart Energy program.
- When informed participants who had not enrolled in the Smart Energy program were asked why they did not enroll, they most often pointed to perceived discomfort from higher thermostat setpoints and warmer homes.[57]
- Accordingly, non-participants who were aware of, but not enrolled in the Smart Energy program most frequently explained that they had not enrolled because they did not know enough about the program. This reason was cited significantly less frequently among their participant counterparts, underscoring the importance of education in increasing participation in the program.

[54] A virtual power plant is a system of decentralized power sources, including demand response, that can be aggregated to meet energy demand and avoid the need for expensive grid infrastructure and power-generating plants.

[55] Southern California Edison, "Demand Response Programs for Homes," https://www.sce.com/residential/demand-response.

[56] To be eligible for the IDSM SCE Smart Energy program, customers must have installed a smart thermostat and not be on a master-meter account. Comprehensive Manufactured program participants were unlikely to have been offered to participate because mobile homes are often master-metered.

[57] However, the program allows customers to override the setpoints.

**Table 4-19. SCE Smart Energy Program awareness and enrollment among Res DI participants and non-participants, PY2021**

| SCE Smart Energy Program | Participants | Non-participants |
|---|---|---|
| | a | b |
| **Awareness** | **(n=1,089)** | **(n=3,483)** |
| Aware/offered to enroll | 52% | 17%a |
| **Enrollment** | **(n=565)** | **(n=580)** |
| Enrolled | 75% | 37%a |
| **Reasons for not enrolling** | **(n=49)** | **(n=182)** |
| Do not want to compromise home comfort | 34%[a] | 13% |
| Privacy or security concerns | 13%[a] | 6% |
| Don't know enough about it | 7%[a] | 34% |
| Insufficient incentives | 5% | 19% |
| Do not use a lot of heating/cooling in my home | 4% | 7% |
| Too complicated | 9%[a] | 3% |
| Unsatisfied with my utility | 0% | 2% |
| Do not use a lot of heating/cooling | 4% | 0% |

Letter superscripts in this table denote values that are statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

### 4.5.3.3 Cost effectiveness calculations

We calculated the two programs' cost effectiveness (CE) based on evaluated savings using the Cost Effectiveness Tool (CET) available on the CEDARS website. Table 4-20 summarizes the PY2021 Res DI program electric and gas savings benefits and the total resource costs associated with these benefits.

**Table 4-20. Res DI program benefits and costs, PY2021**

| Program | Electric benefit | Gas benefit | Program TRC cost |
|---|---|---|---|
| Residential Direct Install (SCE-13-SW-001G) | $445,614 | $480,104 | $10,564,045 |
| Comprehensive Manufactured Homes (SCE-13-TP-001) | $136,857 | $52,204 | $2,023,033 |

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.[58]

We compared the evaluated TRC values with claimed TRC values for the Res DI programs filed in CEDARs. We present these values alongside the initial filed TRCs by the programs in Figure 4-26. As summarized in the figure, the programs filed initial TRC values that were well above 1 and had expected the programs to be cost effective. The claimed values filed by the programs were below one, approximately between 0.5 to 0.6. The evaluated TRC values are a fraction of the claimed values and reflect the low gross realization rates associated with the installed measures.

[58] 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#:~:text=(3)%20The%20Total%20Resource%20Cost,participants%20and%20the%20utility%27s%20costs.

**Figure 4-26. Filed, claimed, and evaluated TRC ratios, PY2021**

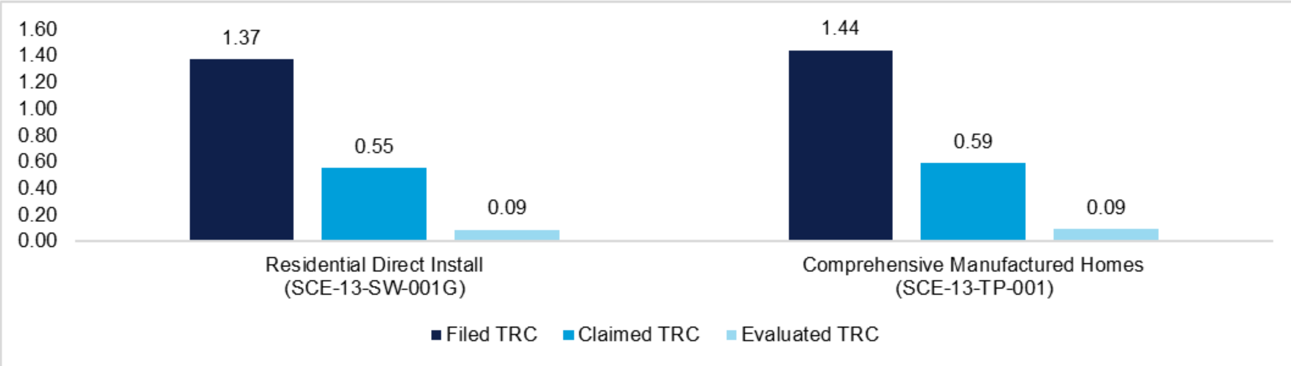



Table 4-21 looks at the system benefits for both Res DI programs. The evaluated gas total system benefits relative to those based on claimed values were much higher than the electric system benefits relative to those based on claimed values, which is in line with the evaluated gross energy savings. Overall, both programs had realization rates of 16% for total system benefits.

**Table 4-21. Total system benefits of Res DI programs, PY2021**

| Program | Claimed | Evaluated | Realization Rate |
|---|---|---|---|
| **Electric** | | | |
| Residential Direct Install (SCE-13-SW-001G) | $ 4,697,570 | $ 445,614 | 9% |
| Comprehensive Manufactured Homes (SCE-13-TP-001) | $ 1,072,861 | $ 136,857 | 13% |
| **Gas** | | | |
| Residential Direct Install (SCE-13-SW-001G) | $ 1,105,873 | $ 480,104 | 43% |
| Comprehensive Manufactured Homes (SCE-13-TP-001) | $ 114,953 | $ 52,204 | 45% |
| **Total** | | | |
| Residential Direct Install (SCE-13-SW-001G) | $ 5,803,443 | $ 925,718 | 16% |
| Comprehensive Manufactured Homes (SCE-13-TP-001) | $ 1,187,814 | $ 189,061 | 16% |

### 4.5.3.4 Barriers to program expansion

During in-depth interviews, SCE and Synergy described barriers that limit program participation. Two market barriers appear to be at play:

**Skepticism—**Synergy concluded that the greatest impediment to program implementation is customer skepticism with fears of scams, particularly with the concept of "no cost." To overcome this market barrier, the programs assigned a liaison to manufactured home communities and gated single-family home communities to build relationships and trust.

**Gatekeepers—**While the program has identified as many as 40,000 potential homes in manufactured housing communities, there are hurdles to connecting with residents. Park managers act as "gatekeepers" to these underserved communities, so program penetration is often dictated by park managers' willingness to allow the programs to connect with residents.

The interviewees noted an internal communication challenge, as well. While SCE has a dedicated energy-efficiency program staff that fields customer calls, if a customer happens to call SCE's main call center, the call center does not always channel customers to the energy-efficiency program staff or even verify the legitimacy of the programs. This may lead to a loss of potential participants.

#### 4.5.3.5 Program data tracking quality

As part of the evaluation's assessment of program delivery, DNV sought to identify if SCE provided program tracking data that is complete, timely, and accurate.

**Timeliness**—The CPUC allows PAs a 10-business day turn-around time to respond to data requests. We used this length of time as a benchmark for measuring timeliness. While the CPUC filed tracking data was complete and accurate, the response to data requests to supplement information reported in the tracking data was lengthy.

We requested program-related information to supplement the tracking data on August 19, 2022, and ultimately received the information on October 3, 2022, approximately a month and a half from the initial request. By contrast, the response to AMI data requests was on time and often sooner than the official deadline. It would benefit the evaluation process to have program-related information request response times mirror the response time to consumption data requests.

**Accuracy—**The quality of program information, including participating customer contact data, has progressively improved over the past three evaluation cycles, and the quality of this year's data reflects this improvement. In general, DNV received more complete usable emails for single-family participants in PY2021 than in past evaluation cycles. On the other hand, the quality of emails for manufactured home participants has been poor.

Although manufactured home residents are often master-metered and share the same utility customer and premise identifiers (customer number and premise number), the tracking data provides the names and addresses of such participants to include in surveys. For most of this group of participants, DNV had received shared emails, which are not usable for contacting individual participants to gather information for program attribution and to understand participant experience. For example, many participants had a Synergy email listed in the information we received.

Table 4-22 provides the percent of usable emails for participants DNV received for the evaluation. The table indicates that percent of manufactured home participants with functional emails was about 32%, which affected DNV's ability to collect information to represent the outcomes and experiences connected to this segment of the participating population.

**Table 4-22. Percent of Res DI participants with usable emails, PY2021**

| Program name | Program ID | All participant sites | Participant sites with contact info | Percent of participants with usable emails |
|---|---|---|---|---|
| **Residential Direct Install** | SCE-13-SW-001G | 12,846 | 9,442 | 74% |
| **Comprehensive Manufactured Homes** | SCE-13-TP-001 | 2,824 | 903 | 32% |

### 4.5.4 Equitable evaluation

Though the CPUC ESJ goals were written after the PY2021 program launched, this evaluation provided an opportunity to assess the programs relative to those goals. Program activities were consistent with:

- Goal 2: Increase investment in clean energy resources [programs] to benefit ESJ communities.

More information is needed to assess how consistent program activities were with the following goals:

- Goal 1: Consistently integrate equity and access considerations throughout CPUC regulatory [and programmatic] activities.
- Goal 3: Strive to improve access to communications for ESJ communities.
- Goal 4.1: Ensure ESJ communities and considerations around their adaptive capacity is incorporated into relevant programs and activities.

- Goal 5: Enhance outreach and public participation opportunities for ESJ communities to meaningfully participate in the CPUC's decision-making process and benefit from CPUC programs.
- Goal 6.1: Protect ESJ Consumers [through equitable programs].
- Goal 8: Improve training and staff development related to ESJ issues within the CPUC's jurisdiction [specifically focused on equitable evaluation].
- Goal 9: Monitor the CPUC's ESJ efforts to evaluate how they are achieving their objectives.

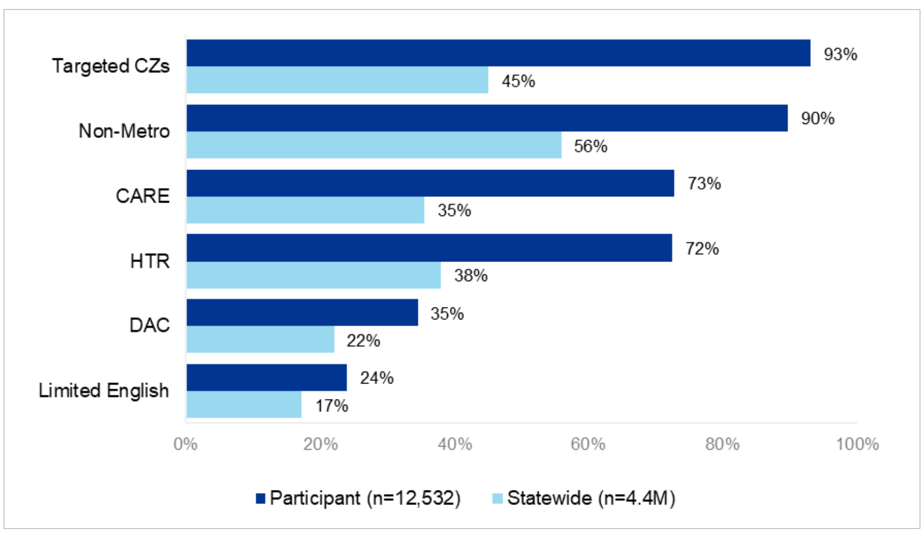
## 4.6 Participant characterization

Using the CIS data and ACS data, we assessed the extent to which the PY2021 Res DI programs served their targeted customers, such as those in DACs. Additionally, we compared the home and occupancy characteristics, energy security, and attitudes toward clean technologies and DR programs between participants and non-participants based on survey responses.

### 4.6.1 Targeted groups

As illustrated in Figure 4-27, the program is successfully fulfilling its goal of engaging certain populations. In comparison to the statewide population, the participant population has notably higher shares of homes in targeted climate zones, non-metro areas, DACs, customers who are on the CARE/FERA rates, HTR, and in households with limited English proficiency.[59]

**Figure 4-27. Locational and demographic comparison between Res DI participant and non-participant populations, PY2021**




Sources: Utility customer information system (CIS) and the American Community Survey (ACS).

The claimed savings for DAC participants accounted for slightly less than one-third of the total claimed Res DI energy and demand savings. The claimed savings for HTR participants accounted for about three-fifths of the overall claimed savings. Table 4-23 shows how single-family participants, compared to manufactured home participants, accounted for most of those savings.

[59] SCE seeks to serve customers in DACs, rural areas, and climate zones 9, 10, 13, 14, and 15, and are HTR. HTR customers are (1) either in non-metro areas or DAC communities, and (2) whose primary household language is not English, or are on CARE/FERA rates, or are renters in multifamily or mobile homes.

**Table 4-23. Percent of claimed energy savings from HTR and DAC participants by housing type, PY2021**

| Demographic group | Dwelling type | Share of claimed savings | | |
|---|---|---|---|---|
| | | Electric energy savings (8,636 MWh) | Demand reduction (4.1 MW) | Gas savings (169,111 therm) |
| DAC | **Overall** | **29%** | **29%** | **31%** |
| | Manufactured homes | 2% | 1% | 1% |
| | Single-family | 27% | 27% | 30% |
| HTR | **Overall** | **59%** | **61%** | **60%** |
| | Manufactured homes | 5% | 3% | 2% |
| | Single-family | 54% | 58% | 58% |

DAC and HTR homes may overlap.

### 4.6.2 Household composition

Table 4-24 compares the number of occupants in the household, overall, and by two age categories based on CIS data. The number of overall occupants as well as the two age groups are well-balanced between participants and non-participants. The majority of households in both the participant and non-participant groups have fewer than 3 occupants. Approximately 30% of both groups of households have no more than 2 residents that are under 18 years old and over 65 years old.

**Table 4-24. Home occupancy, PY2021**

| Count of occupants in home | Participants (n=12,410) | Non-participants (n=12,588) |
|---|---|---|
| **Overall** | | |
| 1 to 2 | 65% | 65% |
| 3 to 5 | 32% | 32% |
| More than 5 | 3% | 3% |
| **Under 18 years old** | | |
| 1 to 2 | 28% | 29% |
| 3 to 5 | 3% | 3% |
| More than 5 | 0% | 0% |
| **65 years and older** | | |
| 1 to 2 | 28% | 29% |
| 3 to 5 | 0% | 0% |
| More than 5 | 0% | 0% |

### 4.6.3 Home characteristics

Table 4-25 compares the home characteristics between participants and non-participants. Home tenure did not differ between the two groups of respondents. However, participants reported living in smaller, newer, and reportedly less well-insulated homes than homes occupied by non-participants, who live in larger, older, and reportedly better-insulated homes. Here are the details on the differences between participant and non-participant homes:[60]

- **Home size—**Non-participants were significantly more likely than participants to live in large homes (2,001 sq. ft. or larger); while participants were significantly more likely to live in medium-sized homes (1,001 to 2,000 sq. ft.).

[60] While differences between percentages may appear subtle, their standard deviations translated to statistically significant differences.

- **Year built—**Participants were significantly more likely than non-participants to have homes built in the 1980s and 1990s, while non-participants were significantly more likely to have homes built before 1980.
- **Insulation—**Larger shares of non-participants than participants reported having insulation in their attics, floors, and walls. Non-participants were significantly more likely than participants to estimate that their attics were well or adequately insulated – participants were significantly more likely than non-participants to estimate that it was poorly insulated.

The California Electronic Technical Reference Manual (CA eTRM)[61] contains attic and wall insulation measures that could be installed through this program. If customer estimates are accurate, there is an opportunity to upgrade insulation for program participants. The CA eTRM previously contained a crawlspace seal and insulate measure (expired in 2022) that could potentially be reinstated and installed through this program.

**Table 4-25. Self-reported home characteristics, PY2021**

| Characteristic | Participants (n=1,089) | Non-participants (n=3,483) |
|---|---|---|
| **Tenure** | | |
| Own | 84% | 86% |
| Rent | 16% | 14% |
| **Size of home (sq. ft.)** | | |
| Less than 250 to 1,000 | 7%[b] | 6% |
| 1,001 to 2,000 | 63%[b] | 57% |
| 2,001 or more | 30%[b] | 36% |
| **Year built** | | |
| Before 1980 | 26%[b] | 32% |
| 1980 to 1999 | 43%[b] | 36% |
| 2000 or later | 31%[b] | 31% |
| **Presence of insulation** | | |
| Attic | 59%[b] | 67% |
| Floor | 9%[b] | 10% |
| Wall | 46%[b] | 53% |
| **Depth of attic insulation** | | |
| Well-insulated (more than 11” of insulation) | 13%[b] | 17% |
| Adequately insulated (8” to 11” of insulation) | 30%[b] | 35% |
| Poorly insulated (less than 8” of insulation) | 17%[b] | 15% |

Sample sizes vary by question due to missing and don’t know responses. Letter superscripts in this table denote values that are statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

### 4.6.4 Energy insecurity

Research has uncovered social economic inequality translates directly into energy inequality and that low-income families are disproportionately affected by energy poverty.[62] Energy insecurity is defined as the inability of a household to meet its basic energy needs for heating, cooling, lighting, and other essential end uses.

Our survey analysis found 43% of participants and 47% of non-participants experienced one or more energy insecurity in the past 12 months. These results are significantly higher than the 2020 U.S. results where 34% of households experienced one

[61] California Electronic Technical Reference Manual, caetrm.com, https://www.caetrm.com/

[62] Radzyminski, Rochelle, “Energy Insecurity in the United States,” large.standford.edu, 12/5/20, http://large.stanford.edu/courses/2020/ph240/radzyminski2/

or more energy insecurity.[63] There are many possible explanations for the differences (e.g., both electric and natural gas costs increased in 2021 due to natural gas supply and infrastructure for wildfire mitigation, and higher costs of living in California).

Table 4-26 presents the shares of customers who reported certain energy insecurities in the last 12 months. Responses did not significantly differ between participants and non-participants in PY2021. However, we noticed a considerable change between PY2020 and PY2021 in the share of respondents who reported that they kept their homes at an unsafe/unhealthy temperature. In PY2021, 1 in 3 customers reported doing so, while in PY2020, fewer than 1 in 10 reported doing so. It is possible that this could be tied to the significantly higher cost of gas prices that have impacted SCE customers and the entire nation.

**Table 4-26. Self-reported energy insecurity, PY2021**

| Challenges in the last 12 months | PY2020 | | PY2021 | |
|---|---|---|---|---|
| | Participants (n=925) | Non-participants (n=3,403) | Participants (n=1,089) | Non-participants (n=3,483) |
| | a | b | c | d |
| Received disconnection, shutoff, or non-received notice for energy bill | n/a | n/a | 12% | 10% |
| Unable to pay some or full bill in the last year | 24% | 13% | 24% | 29% |
| “Heat or eat” forewent basic necessities to pay energy bill in the last year | 36% | 23% | 27% | 26% |
| Kept home at an unsafe/unhealthy temperature in the last year | 10% | 7% | 33% | 34% |

Multiple responses permitted. In PY2020, we did not ask respondents about disconnections, shutoffs, or non-received notices. Letter superscripts in this table denote values that are statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

### 4.6.5 Clean technology adoption

Of the six clean technologies that we asked about, customers most often currently use smart appliances and solar panels (Table 4-27). While similar shares are considering or planning to adopt these in the next two years, customers also commonly have their “sights set on” battery storage and electric vehicles.

**Table 4-27. Customer willingness, consideration, or planning of adoption of clean technology, PY2021**

| Technology | Participants (n=1,089) | Non-participants (n=3,483) |
|---|---|---|
| **Use currently** | | |
| Smart appliances | 33%[b] | 34% |
| Solar panels | 28%[b] | 26% |
| Heat pump water heater | 16%[b] | 15% |
| Heat pump heating/cooling | 14%[b] | 14% |
| Electric vehicles | 8%[b] | 9% |
| Battery storage | 3%[b] | 3% |
| **Would consider or purchase in the next two years** | | |
| Smart appliances | 41%[b] | 38% |

63 Household energy insecurity is measured nationwide though the U.S. Energy Information Administration. U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

| Technology | Participants (n=1,089) | Non-participants (n=3,483) |
|---|---|---|
| Solar panels | 30%[b] | 29% |
| Heat pump water heater | 27%[b] | 25% |
| Heat pump heating/cooling | 24%[b] | 23% |
| Electric vehicles | 32%[b] | 29% |
| Battery storage | 38%[b] | 35% |

Multiple responses permitted. Letter superscripts in this table denote values that are statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

### 4.6.6 Demand response program participation

The participant and non-participant surveys included questions aimed at gauging respondent interest in participating in DR programs. All respondents received an explanation of the benefits of DR programs. Benefits described for participation in a DR program included contributing to electric grid reliability, energy savings through lower energy use, and financial incentives.

Respondent interest in participating in DR programs is summarized in Table 4-28. While fewer program participants than their matched non-participant counterparts indicated they were already enrolled in a DR program, around 70% of both participants and non-participants indicated some level of interest[64] in participating in a DR program. Additionally, compared to PY2020, more than double the participants and non-participants indicated they were already enrolled in a DR program in PY2021.

In response to their preferred DR program participation pathway, around 29% to 38% of participants and matched non-participants indicated that they would stay in the DR program and override any adjustments to their thermostats to suit their needs. Between 22% to 23% indicated that they would stay in the program and allow the program to automatically adjust their thermostat setpoints, similar to PY2020 survey results.

The top three barriers to DR program participation among those who stated that they would not participate in DR programs and would opt out if auto-enrolled are concerns that program participation would compromise the comfort of their home, lack of awareness about DR programs, and insufficient incentives. For participants, the top barrier to participation was concern related to privacy and security when allowing access to household appliances. While there were some differences along these barriers between participants and their non-matched counterparts, the top barriers suggest that broad education and outreach campaigns could be effective.

**Table 4-28. Customer attitudes towards DR programs, PY2020 and PY2021**

| Survey response | PY2020 | | PY2021 | |
|---|---|---|---|---|
| | Participants | Non-participants | Participants | Non-participants |
| | a | b | c | d |
| **Level of interest** | **(n=925)** | **(n=3,403)** | **(n=1,089)** | **(n=3,483)** |
| Already enrolled in demand response | 8% | 3%[a] | 15% | 21%[c] |
| Very interested in demand response | 13% | 14%[a] | 13% | 16%[c] |
| Neutral to very interested or already enrolled in demand response | 58% | 55%[a] | 69% | 68%[c] |
| **Preferred pathway to participation[1]** | **(n=534)** | **(n=1,987)** | **(n=758)** | **(n=2,3089)** |

64 Respondents who rated their level of interest on a five-point scale as 3-5 (Neutral to Very Interested) or already enrolled

| Survey response | PY2020 | | PY2021 | |
|---|---|---|---|---|
| | Participants | Non-participants | Participants | Non-participants |
| | a | b | c | d |
| Would stay in program and during program events, would allow the program to automatically adjust thermostat set points | 22% | 20%[a] | 22% | 23%[c] |
| Would stay in the program, and during program events, would override any adjustments, if it was inconvenient | 33% | 37%[a] | 29% | 38%[c] |
| Would not agree to participate and would opt-out of the program if auto-enrolled | 14% | 9%[a] | 5% | 11%[c] |
| **Barrier[2]** | **(n=70)** | **(n=207)** | **(n=38)** | **(n=250)** |
| Do not want to compromise home comfort | 39% | 53%[a] | 12% | 37%[c] |
| Don't know enough about it | 45% | 32%[a] | 12% | 32%[c] |
| Insufficient incentives | 29% | 27% | 10% | 29%[c] |
| Privacy or security concerns | 10% | 20%[a] | 21% | 23% |
| Do not use a lot of heating/cooling in the home | 15% | 11%[a] | 10% | 13% |
| Currently not satisfied with the utility and therefore would not consider this | 10% | 4%[a] | 3% | 9% |
| Too complicated | 5% | 3% | 5% | 8% |

[1] Samples include those already enrolled or with some level of interest in participating in DR program. [2] Samples include those who would opt out if auto-enrolled in DR programs. Letter superscripts in this table denote values that are statistically significantly different, at least at the 90% confidence level, from the value in the referenced column.

# 5 CONCLUSIONS AND RECOMMENDATIONS

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

|  Key findings |  Implications and recommendations |
|---|---|
| 1. As in the past two program years, direct install smart thermostats have a low gross realization rate. | Although the claimed savings for smart thermostats were revised downwards by approximately 10% starting in PY2024, the continued low gross realization for this measure suggests that the savings need further revision.<br><br>The findings also suggest that programs consider improved customer/contractor training when installing smart thermostats in direct install programs. |
| 2. Direct install **fan motors** also continue to have low realization rates. | We recommend a new HVAC motor baseline study and a revision to the **fan motor replacement measure package** since its baseline fan motor efficiency is based on a 15-year old study. Together with this update, programs should review the criteria for installing these measures. |
| 3. Similarly, direct install **fan controls** have a low realization rate. | The **fan motor control measure package** savings are based on a 2012 SCE study. We recommend a review to understand why the savings based on that study are not realized and a revision of the fan control measure package savings methodology. Together with this review, the programs should re-assess the criteria for installing these measures. |
| 4. The water heating (aerator) measures included in the current evaluation also have a low realization rate. | There are two possible explanations for the low aerator realization rates: 1) inflated unit energy savings due to inaccurate assumptions in the deemed measure package of hot water consumption at sinks or electric water heater presence, or 2) the change in flow rate could be less than assumed or is uncertain. Both explanations require investigation and correction if necessary. |

| Key findings | Implications and recommendations |
|---|---|
| 5. Two of the three HVAC tune-up measures (HVAC fan repair and coil cleaning) delivered close to half of the claimed savings for each measure, while the third (HVAC RCA) only delivered 2% of the claimed savings for the measure. | This finding supports prior decisions to sunset the RCA measure. The measure should remain closed. |
| 6. Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the HVAC consumption and deliver savings during the summer peak demand hours and across all seasons. | Continue to include these measures in the residential HVAC program portfolio. |
| 7. The demographic profiles and evaluated NTGRs indicate that these programs are reaching the right population segments. | Maintain targeting and outreach to these customers. |
| 8. The programs' new integrated demand side management is yielding success. A higher proportion of participants was aware and enrolled in SCE's smart thermostat demand response program compared to non-participants. | Continue to offer information to increase awareness about SCE's demand response programs and offer to enroll participants in these programs at the time of energy efficiency installations. |
| 9. While customers were generally satisfied with the programs, with 87% reporting overall satisfaction, they reported somewhat lower satisfaction with the information and the benefits the programs provided. | Follow up to ensure installed equipment works as intended and provide better education and information, particularly for measures with behavioral aspects, to enable customers to receive the full benefits of the installations. |
| 10. Program activities were consistent with one of the CPUC's ESJ goals and more information is needed to assess consistency with the rest of the CPUC ESJ goals. | Establish an equity metric framework and specific equity- and access-related metrics for all programs. Where a quantitative metric is not practical, guide programs about what activities would be consistent with the ESJ goals. |

# 6 APPENDICES

## 6.1 Appendix A: Gross and net lifecycle savings

Gross and net lifecycle savings are in the attached pdf.

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

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

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

| Study ID | Study Type | Study Title | CPUC Study Manager |
|---|---|---|---|
| **Group A: CALMAC ID CPU0351.01** | Impact Evaluation | Residential Direct Install Program - Program Year 2021 | Peng Gong |

| Rec # | Program or Database | Summary of Findings | Additional Supporting Information | Best Practice / Recommendations | Recipient | Affected Workpaper or DEER |
|---|---|---|---|---|---|---|
| **1** | SCE Residential Direct Install Programs | As in the past two program years, direct install smart thermostats have a low gross realization rate. | Section 4.2 and Section 4.5.3 | Although the claimed savings for smart thermostats were revised downwards by approximately 10% starting in PY2024, the continued low gross realization for this measure suggests that the savings need further revision.<br>The findings also suggest that programs consider improved customer/contractor training when installing smart thermostats in direct install programs. | CPUC, All PAs | Statewide workpaper, Program design consideration |
| **2** | SCE Residential Direct Install Programs | Direct install fan motors also continue to have low realization rates. | Section 4.2 | We recommend a new HVAC motor baseline study and a revision to the fan motor replacement measure package since its baseline fan motor efficiency is based on a 15-year-old study. Together with this update, programs should review the criteria for installing these measures. | CPUC, All PAs | Statewide workpaper |
| **3** | SCE Residential Direct Install Programs | Similarly, direct install fan controls have a low realization rate. | Section 4.2 | The fan motor control measure package savings are based on a 2012 SCE study. We recommend a review to understand why the savings based on that study are not realized and a revision of the fan control measure package savings methodology. Together with this review, the programs should re-assess the criteria for installing these measures. | CPUC, All PAs | Statewide workpaper |

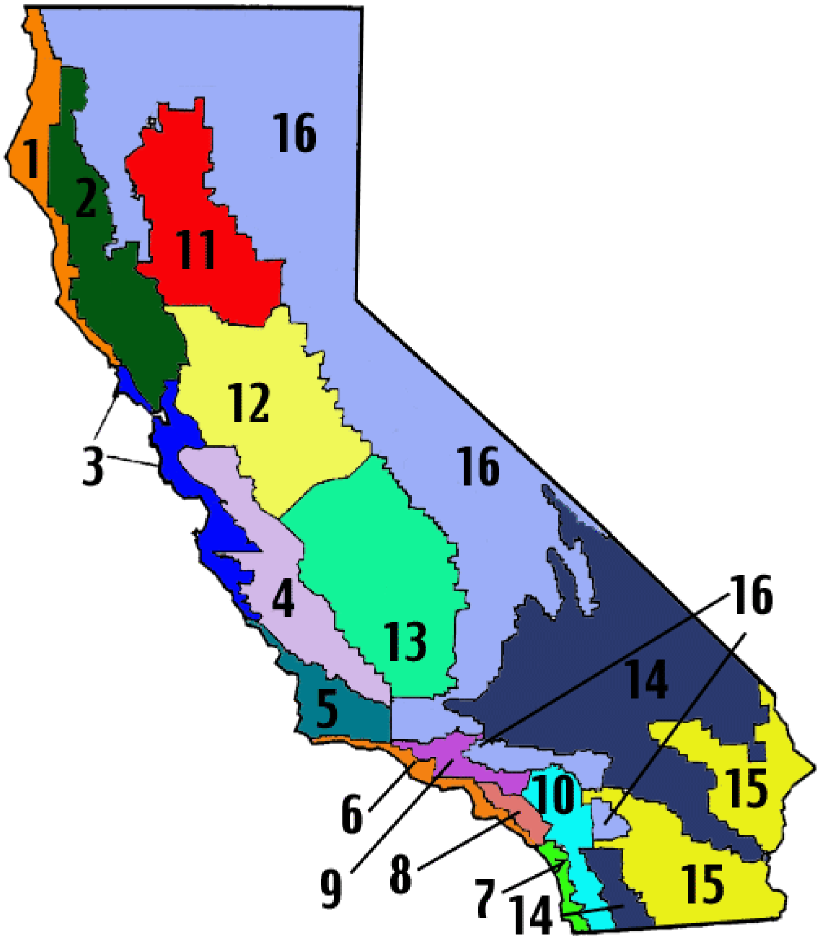
| Rec # | Program or Database | Summary of Findings | Additional Supporting Information | Best Practice / Recommendations | Recipient | Affected Workpaper or DEER |
|---|---|---|---|---|---|---|
| **4** | SCE Residential Direct Install Programs | The water heating (aerator) measures included in the current evaluation also have a low realization rate. | Section 4.2 | There are two possible explanations for the low aerator realization rates: 1) inflated unit energy savings due to inaccurate assumptions in the deemed measure package of hot water consumption at sinks or electric water heater presence, or 2) the change in flow rate could be less than assumed or is uncertain. Both explanations require investigation and correction if necessary. | CPUC, All PAs | Statewide workpaper |
| **5** | SCE Residential Direct Install Programs | Two of the three HVAC tune-up measures (HVAC fan repair and coil cleaning) delivered close to half of the claimed savings for each measure, while the third (HVAC RCA) only delivered 2% of the claimed savings for the measure. | Section 4.2 | This finding supports prior decisions to sunset the RCA measure. The measure should remain closed. | CPUC, All PAs | Statewide workpaper, Program design consideration |
| **6** | SCE Residential Direct Install Programs | Savings shapes indicate that measures like fan motors and duct sealing reduce consumption proportionally to the HVAC consumption and deliver savings during the summer peak demand hours and across all seasons. | Section 4.3 | Continue to include these measures in the residential HVAC program portfolio. | CPUC, All PAs | N/A (Program design consideration) |
| **7** | SCE Residential Direct Install Programs | The demographic profiles and evaluated NTGRs indicate that these programs are reaching the right population segments. | Section 4.2 and Section 4.6 | Maintain targeting and outreach to these customers. | CPUC, All PAs | N/A (Program design consideration) |
| **8** | SCE Residential Direct Install Programs | The programs' new integrated demand side management is yielding success. A higher proportion of participants was aware and enrolled in SCE's smart thermostat demand response | Section 4.5.3 | Continue to offer information to increase awareness about SCE's demand response programs and offer to enroll participants in these programs at the time of energy efficiency installations. | CPUC, All PAs | N/A (Program design consideration) |

| Rec # | Program or Database | Summary of Findings | Additional Supporting Information | Best Practice / Recommendations | Recipient | Affected Workpaper or DEER |
|---|---|---|---|---|---|---|
| | | program compared to non-participants. | | | | |
| **9** | SCE Residential Direct Install Programs | While customers were generally satisfied with the programs, with 87% reporting overall satisfaction, they reported somewhat lower satisfaction with the information and the benefits the programs provided. | Section 4.5.3 | Follow up to ensure installed equipment works as intended and provide better education and information, particularly for measures with behavioral aspects, to enable customers to receive the full benefits of the installations. | CPUC, All PAs | N/A (Program design consideration) |
| **10** | SCE Residential Direct Install Programs | Program activities were consistent with one of the CPUC's ESJ goals and more information is needed to assess consistency with the rest of the CPUC ESJ goals. | Section 4.5.4 | Establish an equity metric framework and specific equity- and access-related metrics for all programs. Where a quantitative metric is not practical, guide programs about what activities would be consistent with the ESJ goals. | CPUC, All PAs | N/A (Program design consideration) |

## 6.4 Appendix D: Climate zones

The California Energy Commission has established 16 climate zones (Title 24 climate zone or CEC CZs) that reflect the diversity of climates in the state (Figure 6-1). Efficiency standards developed and adopted for various building and measure conditions reflect the varying effect of the CEC CZs.

**Figure 6-1. California CEC climate zones**




To develop survey weightings, we have grouped the 16 CEC CZs into four climate regions: coastal, inland, desert, and mountain. Table 6-1 provides these groupings along with the percentage of participants by climate region.

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

| Climate region | CEC climate zone | SCE |
|---|---|---|
| **Coastal/Mild** | 1,2,3,4,5,6,7 | 0% |
| **Inland** | 8,9,10,11,12,13 | 85% |
| **Desert** | 14,15 | 12% |
| **Mountain** | 16 | 3% |

## 6.5 Appendix E: Two-stage modeling framework

The consumption data analysis that is the basis of measure savings estimates we used, involved a two-stage modeling that combined variable degree-day PRISM-inspired,[65] site-level models with a matched comparison group to estimate program-level estimates in a difference-in-difference (DID) framework. This is a well-established and accepted methodology that is appropriate for the evaluation of energy changes at the home level after an energy efficiency intervention.

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

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

The methodology is also consistent with the approach laid out in the Uniform Methods Project (UMP) Chapter 8 modeling approach, which provides whole house savings estimation protocols for energy efficiency interventions that have whole home impacts like smart thermostats.[66] The modeling approach is also closely related to all other forms of program analysis that use energy consumption data including time-series and cross-section approaches. Finally, it is also consistent with CalTRACK's recent effort to develop agreed-upon steps for the site-level modeling portion of the analysis.[67]

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

The two-stage approach relies on the comparison group to control for non-program, exogenous change. It assumes that the comparison group is a reasonable proxy for the counterfactual of the participant group. The intent of matching as a basis for choosing a comparison group is to develop a group that has similar characteristics and can serve this purpose. However, though matched on pre-period consumption and various other characteristics, the approach still must assume that participant and comparison groups have similar underlying trends over time. To the extent there are differential underlying trends, the savings estimates may be biased up or down. The comparison group may over- or under-compensate for the trend in participant consumption over time, over- or underestimating savings in the process.

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

### 6.5.1 Site-level modeling

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

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

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

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

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

Where:

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

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

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

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

$\tau_h$ - Heating base temperatures, determined by choice of the optimal regression.

$\tau_c$ - Cooling base temperatures, determined by choice of the optimal regression.

$\varepsilon_{im}$ – Regression residual.

We estimated site-level models using daily energy use data and observed weather data from the NOAA. Consumption was estimated over a range of reference temperatures (64°F to 80°F for cooling and 50°F to 70°F for heating) to identify the optimal temperature base points for each site (household. The site-level models produced parameters that indicate the level of energy consumption not correlated with either HDD or CDD (baseload), and the levels of energy consumption correlated with HDD (heating load) or CDD (cooling load). First-stage models were screened to remove estimates that had implausible (negative) cooling and heating coefficients.

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

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

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

### 6.5.2 Matched comparison group construction

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

We constructed matched comparison groups from general population customers for the two-stage consumption data analysis. This effort involved two phases. The first phase identified 20 households for every participant with similar energy use levels (based on monthly billing data) and trends (proxied by tenure[68]) within strata defined by dwelling type and

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

geography. In the second phase, 1-to-1 matches were based on interval consumption data to choose the optimal household from the initial 20 matches.

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

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

The standardized mean difference used to test the condition of matches is given by:

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

A standardized mean difference value that exceeds 0.2 shows extreme imbalance, while the closer to 0 this value gets, the better the condition of matching. For the variance ratio, a value close to 1 indicates balance while values that are 0.5 or less and 2 or greater indicate extreme imbalance.[69]

### 6.5.3 DID modeling

To determine the whole home energy consumption effects of direct install programs, we estimated DID models based on the pre-to-post difference in NAC of participants and the matched comparison households.[70] This model is given by:

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

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

Pre- and post-program periods were based on a definition of a blackout period for each participant. According to CalTRACK, a blackout period is a "time between the end of the baseline period and the beginning of the reporting period in which a project is being installed." It advises the use of "the earliest intervention date as the project start date and the latest date as the project completion date."[71] Based on the CalTRACK recommendation and the IOU-provided tracking data, we defined a blackout period that reflects installation months reported in the tracking data for all the measures installed by the direct install programs that delivered the measure bundles including smart thermostats.

## 6.6 Appendix F: Matching results

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

[69] 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

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

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

select such matched comparison households. Tests of balance between participant and selected comparison group customers show improvements in the condition of matching with each phase.

### 6.6.1 First-phase matching results

Table 6-2 provides values of the metrics used to test balance. These metrics are computed based on annual consumption of participants and selected candidate matches after matching. In general, standardized mean differences and the ratios of variance of annual consumption for the matched groups show that the selected 20:1 match is relatively well balanced. The standardized difference for the matched group is 0.006 and the ratio of variance is close to 1, generally indicating the variance of annual usage of the matched group is similar.

**Table 6-2. First-phase matching test of balance**

| Standardized mean difference | Variance ratio |
| --- | --- |
| **0.006** | 1.0 |

### 6.6.2 Second-phase matching results

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

Interval data from the 20:1 participant to non-participant matches based on monthly billing data were the basis of the second phase 1:1 matches. These matches led to the selection of non-participant households that were best matches for the participants. These matches provide the conditions for a robust analysis of the effect of direct install measures on energy consumption changes since they control for non-program related changes effectively.

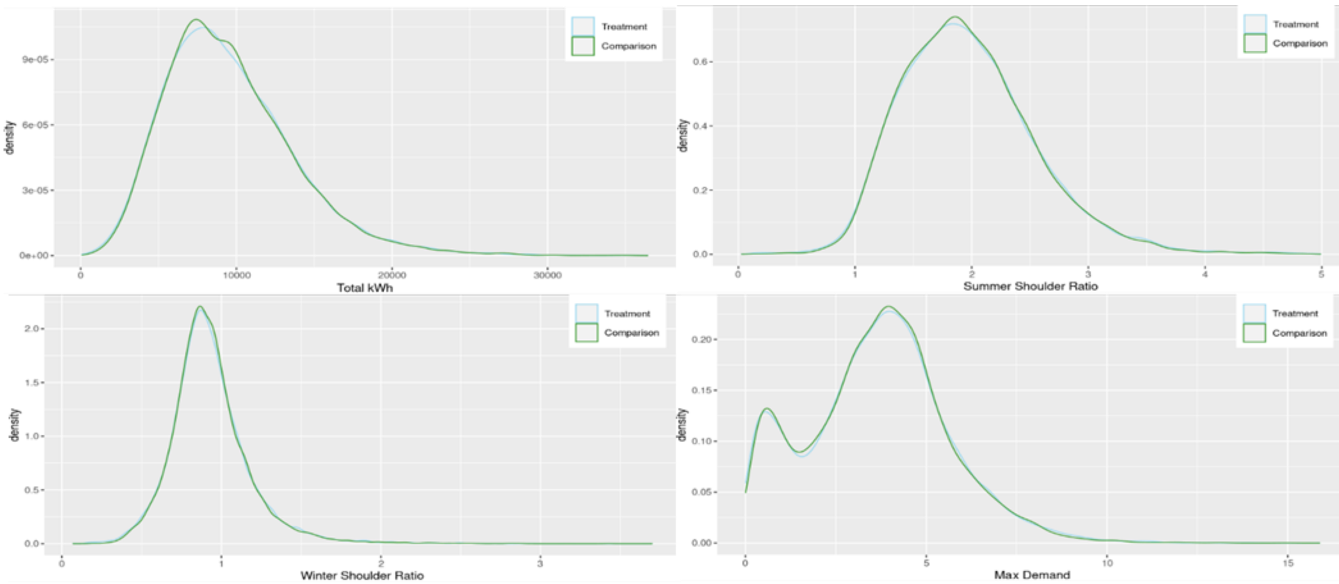
The metrics used to test the condition of balance indicate that the selected 1:1 matches in this phase of matching are well-balanced. As in the first-phase matching, the total consumption of the matched groups was used to compute the test of balance metrics. The standardized mean differences are near zero, with 95% confidence bounds that in absolute value are no higher than 0.06. Tests of balance on all other matching variables including tenure indicated that the two groups used in the analysis had well-balanced data.

**Table 6-3. Second-phase matching test of balance**

| Standardized mean difference | Variance ratio |
| --- | --- |
| **0.004** | 1.0 |

Figure 6-2 illustrates the quality of matches for the selected matched samples graphically. The panel provides the distribution of variables for participant and matched non-participant homes. It indicates that these distributions are very similar and that the data is well-balanced.

**Figure 6-2. Distribution of SCE-matched electric data**




## 6.6.3 Quality of matches from additional variables

In addition to testing the balance on consumption data used for the matching, we tested the condition of balance based on additional household characteristics data that the IOUs provided. Figure 6-3 through Figure 6-6 below show the distributions of these characteristics for participants and their matched comparison groups, respectively, where the matches were based on consumption and tenure only. The figures show good correspondence between the participants and matched comparison groups on these additional dimensions.

**Figure 6-3. Comparison group assessment by ownership status**

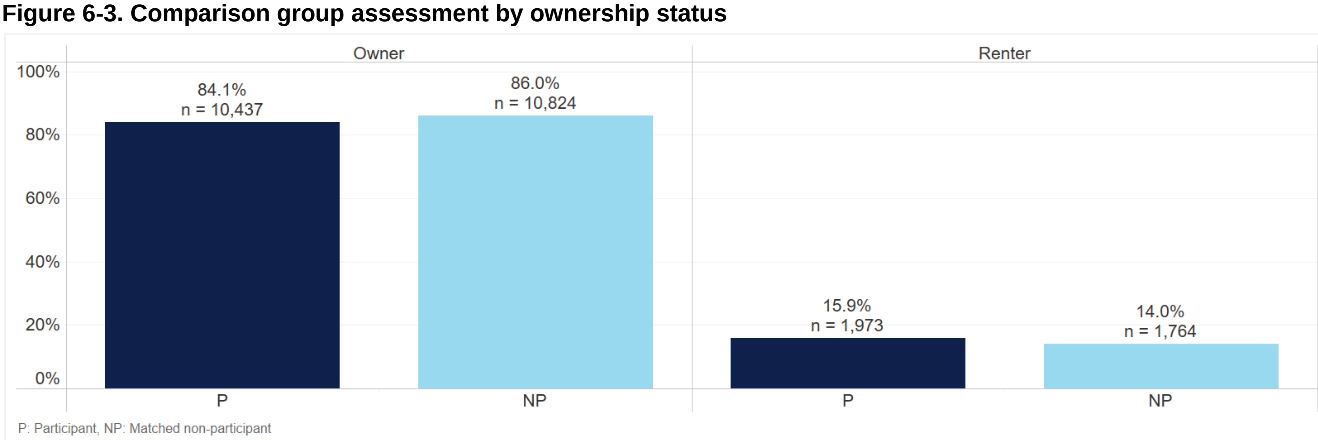


**Figure 6-4. Comparison group assessment by household income**

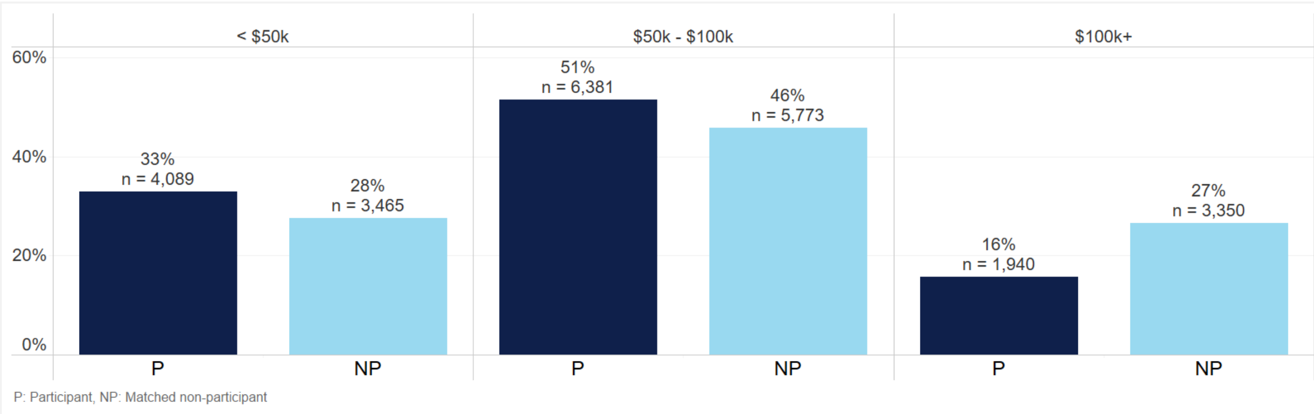



**Figure 6-5. Comparison group assessment by number of children in home**

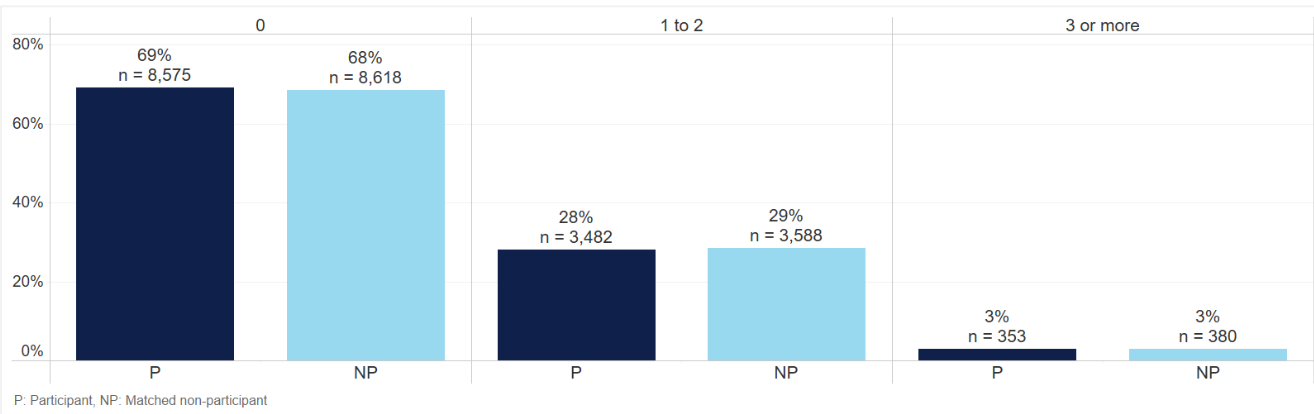
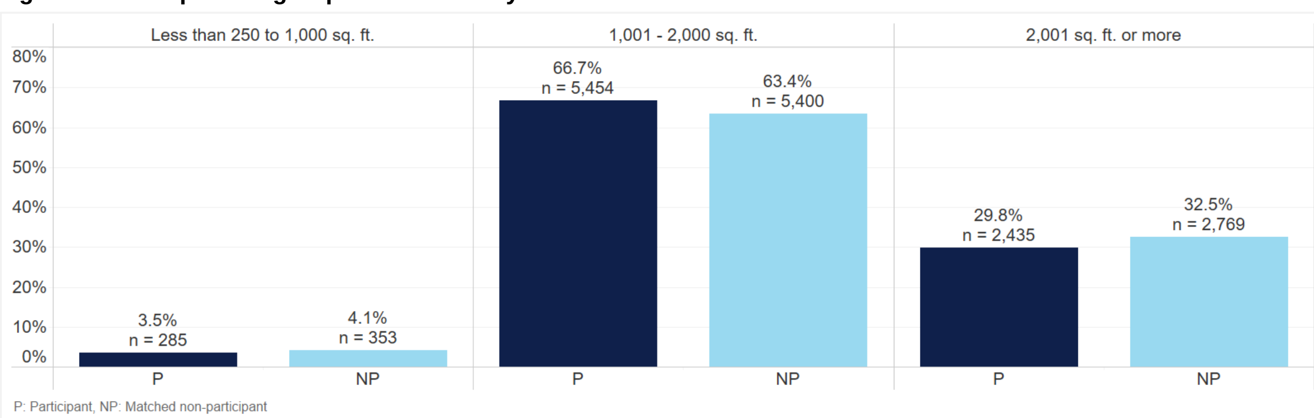



**Figure 6-6. Comparison group assessment by size of home**




## 6.7 Appendix G: Second stage DID model results

This section presents all second stage DID model results.

### 6.7.1 Direct install models

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

A further step recognizes that savings are likely to vary as a function of the size of a home. To increase model flexibility that addresses this, both sides of the regression are divided by consumption to put variables on a percentage basis. The pre-post consumption dependent variable is divided by pre-period consumption while the bundle of engineering simulation value on the right side is divided by simulation model baseline consumption. Again, the regression determines the mix of the constant dummy and percent simulated measure bundle savings effects that best reflects the empirical data entering the model in the dependent variable. Details of this model are provided in Section 3.2

Table 6-4 provides percent change DID model results that are the basis of the percent electric baseload changes for customers that participated in direct install programs. These models indicate no evidence of an increasing energy consumption trend for these participants.

**Table 6-4. Direct install electric baseload savings models by dwelling type, PY2021**

| Model type | Variable | Dwelling type | N | Estimate | Standard error | P-value |
|---|---|---|---|---|---|---|
| **Baseline baseload** | Intercept | Mobile home | 752 | 3,791 | 69 | 0.00 |
| | | Single-family | 6,805 | 5,515 | 32 | 0.00 |
| | treat | Mobile home | 752 | 44 | 98 | 0.65 |
| | | Single-family | 6,805 | -25 | 45 | 0.58 |
| **Percent change difference-in-difference** | Intercept | Mobile home | 752 | 0.01 | 0.01 | 0.30 |
| | | Single-family | 6,805 | 0.01 | 0.00 | 0.00 |
| | treat | Mobile home | 752 | 0.00 | 0.01 | 0.80 |
| | | Single-family | 6,805 | 0.00 | 0.00 | 0.95 |

Table 6-5 provides results from the percent change model. The general trend estimates ($B\_t$) indicate a decline in energy use if positive and an increase if positive. The adjustment factors ($B\_adj$) reflect what fraction of expected savings of the installed measures were realized by the mix of measures installed by the direct install programs.

**Table 6-5. Direct install electric models of percent change in annual whole home consumption**

| Dwelling type | Intercept | P-value | *B_t* | P-value | *B_adj* | P-value |
|---|---|---|---|---|---|---|
| **Mobile home** | 0.020 | 0.001 | -0.008 | 0.462 | 0.237 | 0.072 |
| **Single-family** | 0.024 | 0.000 | 0.004 | 0.189 | 0.066 | 0.377 |

Whole home consumption change estimates from the above model are disaggregated using the proportion of simulated energy savings of installed measures at each site as indicated in Section 3.2. Table 6-6 provides estimates of both whole home and measure level electric savings.

**Table 6-6. Direct install electric whole home and measure-level savings models by dwelling type, PY2021**

| Model type | Dwelling type | Model estimates | | |
|---|---|---|---|---|
| | | Savings (kWh) | Standard error | P-value |
| **Whole home** | Mobile home | 34 | 53 | 0.5 |
| | Single-family | 56 | 24 | 0.0 |
| **Smart thermostats** | Mobile home | 4 | 30 | 0.9 |
| | Single-family | 30 | 16 | 0.1 |

| Model type | Dwelling type | Model estimates | | |
|---|---|---|---|---|
| | | Savings (kWh) | Standard error | P-value |
| **Fan motor replacement** | Mobile home | 108 | 61 | 0.1 |
| | Single-family | 60 | 28 | 0.0 |
| **Fan motor controls** | Mobile home | 37 | 41 | 0.4 |
| | Single-family | 39 | 15 | 0.0 |
| **Duct testing and sealing** | Mobile home | 117 | 63 | 0.1 |
| | Single-family | 83 | 40 | 0.0 |
| **Coil cleaning** | Mobile home | 14 | 23 | 0.5 |
| | Single-family | 21 | 8 | 0.0 |
| **Fan repair** | Mobile home | 4 | 7 | 0.6 |
| | Single-family | 6 | 2 | 0.0 |
| **Refrigerant charge adjustment** | Mobile home | -6 | 16 | 0.7 |
| | Single-family | 15 | 10 | 0.1 |
| **Water heating (aerator)** | Mobile home | 1 | 29 | 1.0 |
| | Single-family | | | |

As a check on the disaggregated savings, we also estimated savings for measures that are installed alone. Smart thermostats were the only measure installed alone in sufficient numbers for use in models. Table 6-7 provides estimates of electric savings from smart thermostats installed alone through direct install programs.

**Table 6-7. Direct install electric savings models for smart thermostat-only installation by dwelling type, PY2021**

| Model type | Dwelling type | N | Model estimates | | |
|---|---|---|---|---|---|
| | | | Savings (kWh) | Standard error | P-value |
| **Whole home** | Mobile home | 122 | -120 | 143.6 | 0.4 |
| | Single-family | 2,507 | 60 | 39.6 | 0.1 |

### 6.7.2 Savings adjustment for comparison group smart thermostat installations

Smart thermostat savings estimates for direct install participants were adjusted upward to account for the prevalence of smart thermostats among the comparison group. Results from surveys of direct install comparison group households revealed that 24% to 34% installed smart thermostats in 2021 (Table 6-8). These are periods during which participants installed smart thermostats and the effect of smart thermostats on energy consumption are measured for this group. If comparison group smart thermostat installations are assumed to have the same savings effect in the matched comparison households as program thermostats, then their presence will have the effect of diminishing the magnitude of participant savings estimates coming directly from the model coefficients.

**Table 6-8. Smart thermostat non-participant and participant user profile, PY2021**

| Characteristic | Participants, manufactured homes (n=128) | Participants, single-family (n=961) | Non-participants, manufactured homes (n=298) | Non-participants, single-family (n=3,185) |
|---|---|---|---|---|
| | a | b | c | d |
| Have a smart thermostat | 74% | 95% | 24% | 34% |

Table 6-9 provides the installation rates of smart thermostats among the comparison group and the multiplicative adjustment factors used to account for these rates by dwelling type. For example, a prevalence of 16.1% smart thermostats among comparison group households requires that savings estimates be divided by (1-0.161 = 0.839) or multiplied by its reciprocal (1.19). This is a modest upward adjustment that assumes that all comparison group installations perfectly correlate with the timing of program participant installations.

**Table 6-9. Adjustment factors for the presence of smart thermostats among the comparison groups by dwelling type, PY2021**

| Dwelling type | PY2021 Installations | Effect on estimated savings |
|---|---|---|
| Mobile home | 11.7% | 1.13 |
| Single-family | 16.1% | 1.19 |

### 6.7.3 Electric measure and whole home savings estimates by dwelling type and climate zone

Table 6-10 provides measure and whole home electric (kWh) savings by dwelling type and climate zone.

**Table 6-10. Measure and whole home electric (kWh) savings by dwelling type and climate zone, PY2021**

| Dwelling type | Climate zone | Whole home | Smart thermostat | Fan motor replacement | Fan motor controls | Duct testing and sealing | Coil cleaning | Fan repair | Refrigerant charge adjustment | Water heating (aerator) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mobile home** | 6 | -23 | -23 | | | | | | | |
| | 8 | 4 | -3 | 56 | 19 | 83 | | | -6 | -4 |
| | 9 | 12 | -3 | | 30 | 76 | | | -40 | 25 |
| | 10 | 42 | 1 | 108 | 39 | 123 | 12 | 4 | -1 | 3 |
| | 13 | 40 | 17 | 66 | 37 | 103 | | | -11 | 10 |
| | 14 | 39 | -4 | 104 | 50 | 103 | | | 2 | -4 |
| | 15 | 40 | 9 | 142 | 59 | 132 | 37 | 10 | 2 | -17 |
| | 16 | 36 | 8 | | 22 | | 13 | 4 | 3 | 12 |
| **Single-family** | 6 | 31 | 31 | | | | | | | |
| | 8 | 39 | 30 | 58 | 30 | 56 | | | 20 | |
| | 9 | 41 | 30 | 54 | 31 | | | | 30 | |
| | 10 | 53 | 38 | 64 | 38 | 83 | 20 | 6 | 14 | |
| | 13 | 60 | 16 | 55 | 39 | 64 | 28 | 8 | 17 | |
| | 14 | 57 | 38 | 66 | 40 | 75 | 24 | 7 | 11 | |
| | 15 | 65 | 46 | 90 | 65 | 115 | | | 16 | |
| | 16 | 49 | 23 | 51 | 16 | 90 | 3 | 1 | 5 | |

## 6.8 Appendix H: Electric load by dwelling type and climate zone

Table 6-11 provides estimates of the average electric baseload, cooling, and heating load across all direct install participants by dwelling type and climate zone. It also includes NAC, which is the sum of the three components, along with the count of households (N) with data in each dwelling type and climate zone.

**Table 6-11. Direct install electric load components by dwelling type and climate zone, PY2021**

| Dwelling type | climate zone | N | Baseload | Cooling load | Heating load | NAC |
|---|---|---|---|---|---|---|
| Mobile home | 6 | 1 | 6,443 | 1,410 | 0 | 7,854 |
| | 8 | 108 | 3,292 | 861 | 146 | 4,298 |
| | 9 | 38 | 4,212 | 1,874 | 133 | 6,219 |
| | 10 | 299 | 4,138 | 2,435 | 125 | 6,698 |
| | 13 | 213 | 3,758 | 2,683 | 221 | 6,663 |
| | 14 | 24 | 4,436 | 2,174 | 486 | 7,096 |
| | 15 | 45 | 3,907 | 4,628 | 202 | 8,737 |
| | 16 | 15 | 3,630 | 1,371 | 401 | 5,402 |
| Single-family | 6 | 6 | 4,719 | 1,471 | 77 | 6,266 |
| | 8 | 173 | 5,517 | 1,485 | 163 | 7,165 |
| | 9 | 67 | 5,262 | 1,800 | 251 | 7,313 |
| | 10 | 2955 | 6,114 | 2,922 | 169 | 9,205 |
| | 13 | 2534 | 5,073 | 3,347 | 264 | 8,684 |
| | 14 | 536 | 6,238 | 2,690 | 391 | 9,319 |
| | 15 | 377 | 5,169 | 5,170 | 101 | 10,440 |
| | 16 | 152 | 5,783 | 2,176 | 492 | 8,451 |

## 6.9 Appendix I: Program installation costs

The implementation contractor budgets to deliver the PY2021 Res DI programs included administration, marketing, and direct implementation costs. The implementer spent $10,564,045 to deliver the Residential Direct Install Program and $2,840,512 to deliver the Comprehensive Manufactured Homes Program. Program spending per unit for each measure is summarized in Table 6-12. The table also provides information on average cost ranges to install each measure. This information was applied to the participant surveys and informed participants of their measure level costs.

**Table 6-12. Program cost by measure group, PY2021**

| Program ID | Measure group | Unit cost | Fully installed average cost range |
|---|---|---|---|
| SCE-13-SW-001G | HVAC coil cleaning | $16 | $100-$200 |
| | HVAC controls fan | $80 | $200-$400 |
| | Smart thermostat | $194 | $120-$250 |
| | Duct test and sealing | $50 | $600 - $1000 |
| | HVAC fan repair | $15 | $200-$400 |
| | Fan motor replacement | $359.98 | $250 - $400 |
| | Refrigerant charge adjustment | $220.25 | $100-$200 |
| SCE-13-TP-001 | HVAC coil cleaning | $16 | $100-$200 |

| Program ID | Measure group | Unit cost | Fully installed average cost range |
|---|---|---|---|
| | HVAC controls fan | $145 | $200-$400 |
| | Smart thermostat | $204 | $120-$250 |
| | Duct Test and sealing | $50 | $600 - $1000 |
| | HVAC fan repair | $15 | $200-$400 |
| | Fan motor replacement | $359.98 | $250 - $400 |
| | Refrigerant charge adjustment | $220.25 | $100-$200 |
| | Water heating faucet aerator | $5-$12 | $5-$15 |
| | Water heating showerhead | $30 | $5-$15 |

## 6.10 Appendix J: NTGR survey scoring

For the Res DI programs, DNV used a standard NTGR approach that assesses three dimensions of free-ridership: timing, quantity, and efficiency. The programs induce savings if they accelerate the timing of measure installation, increase the number of measures installed, or raise the efficiency level of what was installed.

The timing dimension is relevant to all measures. Quantity and efficiency are relevant for certain measures and not for others. For example, it is almost always the case that the entire duct system is treated at once, so quantity would always be one. Similarly, the ducts are either sealed or not, so there is not a variable level of efficiency as there would be for a furnace. The following measures and dimensions are covered in the PY2021 evaluation:

1. **Smart thermostats (timing, efficiency)** - For smart thermostats, the survey determined “efficiency” in terms of the type of thermostat that would otherwise have been installed but rated these at only 2 levels—smart (efficient) or not. Res DI program participants could only receive a single smart thermostat so that the quantity dimension is not applicable.
2. **Fan motor replacement (timing, efficiency)** – Fan motors could be repaired or replaced with a standard rather than a brushless motor, therefore the efficiency dimension is relevant for fan motors. For both residential direct install programs, a quantity of one is assumed for fan controls.
3. **Fan motor controls (timing)** – We assumed a single fan motor per household. As a controller, it is either installed or not – there are no varying levels of efficiency for fan motor controllers.
4. **Duct sealing (timing)** – As noted above, duct sealing happens for the entire home and there are no variable levels of efficiency and quantity.
5. **Showerhead (timing, quantity)** – For showerheads, there are no varying levels of efficiency, but the quantity dimension is applicable.
6. **Faucet aerator (timing, quantity)** – Similarly to showerheads, faucet aerators do not have varying levels of efficiency, but the quantity dimension is applicable.

The NTGR survey scoring elements are summarized below in Table 6-13.

**Table 6-13. Free-ridership elements by survey respondent type, PY2021**

| Free-ridership Dimension | Measures Applicable | Question Wording | Answer | Free-Ridership Score |
|---|---|---|---|---|
| Timing - ($FR_t$) | All measures | Without the program offering on [INSTALL DATE], when would you | At the same time or sooner | 1 |

| Free-ridership Dimension | Measures Applicable | Question Wording | Answer | Free-Ridership Score |
|---|---|---|---|---|
| | | have completed this project? | 1 to 24 months later | (24 - # of months)/24 |
| | | | More than 24 months later | 0 |
| | | | Never | 0 |
| | | | Don't know | Average of non-Don't know answers |
| Efficiency - ($FR_e$) | Smart thermostats | Smart thermostats come in a variety of models. There are BASIC models that cost about $120 to $150 (e.g., Nest E, Ecobee3 lite, Honeywell T5) and UPGRADED advanced models that offer additional sensing technology (e.g., Nest Learning 3rd Gen, Ecobee 4, Honeywell T9) and cost about $210 to $250. And there a programmable and non-programmable thermostats which costs range from $20 to $100. If the program didn't offer a smart thermostat in 2021, which model would you have likely purchased? | Would have purchased the BASIC model smart thermostat(s) | 1 |
| | | | Would have purchased the UPGRADED model smart thermostat(s) | 1 |
| | | | Would have purchased standard programmable thermostat(s); (e.g., without smart capabilities) | 0 |
| | | | Would NOT have purchased any thermostat(s) | 0 |
| | Fan motor replacements | We would also like to know what influence the program had, if any, on the decision to have a technician install a new FAN MOTOR on the furnace. Without the program, which of the following would you have done? | Replace with a high efficiency motor (i.e., brushless) similar to the one I received from the program | 1 |
| | | | Replace with a standard motor | 0 |
| | | | Repair the existing equipment | 0 |
| | | | Nothing, no replacement, or repair | 0 |
| Quantity- ($FR_q$) | Showerheads and faucet aerators | Without the program, how many | None | 0 |

| Free-ridership Dimension | Measures Applicable | Question Wording | Answer | Free-Ridership Score |
|---|---|---|---|---|
| | | [showerheads/aerators] would you have installed at your own expense? | 1 | 1 - (n - answer) / n), where n is the number of measures installed through the program |
| | | | 2 | |
| | | | 3 | |
| | | | 4 | |
| | | | 5 or more | |
| | | | Don't know | Average of non-Don't know answers |

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

Equation 1: Free-ridership Scoring Algorithm for smart thermostats and fan motor replacements

*Free-ridership= FR_timing score * FR_efficiency score*

Equation 2: Free-ridership Scoring Algorithm for fan motor controls and duct sealing

*Free-ridership= FR_timing score*

Equation 3: Free-ridership Scoring Algorithm for showerheads and faucet aerators

*Free-ridership= FR_timing * FR_quantity*

Program attribution or NTGRs are simply the complement of free-ridership and estimated as: *NTGR = 1- Free-ridership.*

Results from the free-ridership analysis based on the participant survey responses are summarized in Section 4.2.3. Program level NTGRs derived from participant surveys are weighted by savings claims to compute program attribution estimates.

## 6.11 Appendix K: NTGR survey results

Participant survey based free-ridership estimates are weighted by electric gross savings claims to arrive at final electric program attribution estimates. Responses reveal a general pattern of lower levels of free-ridership and higher program attribution of kWh savings for HTR participants relative to Non-HTR participants at 77% to 83% for the Residential Direct Install Program and 73% to 81% for the Comprehensive Manufactured Homes program. Of the total electric gross savings claims, the Residential Direct Install Program contributed 79% of savings compared to 21% from the Comprehensive Manufactured Homes program.  Program attribution scores for electric savings for residential direct install measures (NTGRs) by program and HTR are summarized in Table 6-14.

**Table 6-14. NTGRs for electric savings for residential direct install measures by program and HTR**

| Program ID | Program name | Gross savings claims (kWh) | % Savings | NTGR | | Relative Precision +/- |
|---|---|---|---|---|---|---|
| | | | | Non-HTR | HTR | |
| **SCE-13-SW-001G** | Residential Direct Install Program | 3,966,285 | 79% | 83% | 77% | 1.6% |
| **SCE-13-TP-001** | Comprehensive Manufactured Homes | 1,027,914 | 21% | 81% | 73% | 3.8% |

Table 6-15 summarizes NTGRs for electric savings by measure, dwelling type, and HTR. For various measures from the program below we did not obtain responses from HTR participants. In these cases, the cells do not have a value in the NTGR HTR column. For most measures, there is higher attribution for HTR versus Non-HTR apart from mobile home duct sealing, faucet aerators, and showerheads.

**Table 6-15. NTGRs for electric savings for residential direct install measures by measures, dwelling type, and HTR**

| Measure | Dwelling type | Gross savings claims (kWh) | % Savings | NTGR | | Relative precision +/- |
|---|---|---|---|---|---|---|
| | | | | Non- HTR | HTR | |
| Smart thermostat | Single-family | 2,066,096 | 41% | 84% | NA | 2% |
| | Mobile Home | 414,292 | 8% | 84% | NA | 5% |
| Fan motor replacements | Single-family | 762,230 | 15% | 88% | 85% | 4% |
| Fan motor controls | Single-family | 1,138,172 | 23% | 74% | 74% | 3% |
| | Mobile Home | 341,106 | 7% | 78% | 69% | 7% |
| Duct sealing | Single-family | 44,932 | 1% | 93% | | 6% |
| | Mobile Home | 42,213 | 1% | 81% | 96% | 18% |
| Showerhead | Mobile Home | 91,000 | 2% | 82% | 90% | 10% |
| Faucet aerator | Mobile Home | 94,158 | 2% | 82% | 93% | 15% |

## 6.12 Appendix L: Sample weights

DNV presents summaries of the sample weights developed for the net attribution analysis (NTGR) and demographic surveys in this section.

**Participant net attribution analysis:** For the net attribution analysis, we merged the survey data with the program tracking data by customer and measure. Weights were calculated by program, measure type, building type, and hard-to-reach status. Within each of these cells, weights were calculated using a simple random sampling approach due to the uniformity of measure savings within a specific measure type. Table 6-16 presents the post stratification weights for the participant survey NTG results.

DNV

**Table 6-16. Participant NTGR survey post stratification weights**

| Building Type | Measure Name | Stratum | Maximum First Year Savings (btu) | Accounts | First Year Savings (btu) | Sample |
|---|---|---|---|---|---|---|
| Mobile Home | Faucet Aerator | 1 | 920,949 | 1,030 | 378,044,302 | 32 |
| | HVAC Duct Test and Seal | 2 | 3,526,945 | 181 | 288,550,855 | 12 |
| | HVAC Indoor Coil Cleaning | 3 | 290,837 | 24 | 4,065,125 | 1 |
| | HVAC Indoor Fan Motor Controller | 4 | 2,926,593 | 1,095 | 1,535,660,734 | 57 |
| | HVAC Indoor Fan Motor Replacement | 5 | 2,577,957 | 180 | 186,463,485 | 4 |
| | HVAC Indoor Fan Repair | 6 | 82,598 | 36 | 1,756,546 | 2 |
| | HVAC Refrigerant Replacement | 7 | 6,434,250 | 314 | 706,909,984 | 12 |
| | Showerhead | 8 | 1,456,542 | 719 | 373,781,207 | 17 |
| | Smart Thermostat | 9 | 4,968,106 | 1,719 | 3,119,434,935 | 93 |
| Single Family | HVAC Duct Test and Seal | 10 | 6,144,451 | 310 | 591,413,681 | 27 |
| | HVAC Indoor Coil Cleaning | 11 | 339,121 | 114 | 17,797,126 | 7 |
| | HVAC Indoor Fan Motor Controller | 12 | 8,740,777 | 4,689 | 5,245,016,860 | 277 |
| | HVAC Indoor Fan Motor Replacement | 13 | 4,053,894 | 1,905 | 1,781,160,083 | 114 |
| | HVAC Indoor Fan Repair | 14 | 96,311 | 117 | 5,166,230 | 7 |
| | HVAC Refrigerant Replacement | 15 | 9,453,835 | 3,400 | 7,649,810,425 | 186 |
| | Smart Thermostat | 17 | 5,392,032 | 10,860 | 23,345,766,328 | 901 |

**Demographic survey analysis:** To calculate site level weights for the participant and non-participant survey respondent demographics analysis, we merged the completed surveys with the billing data. Customers in both groups were then stratified based on their annual kWh for those customers where consumption data was available. For the matched non-participants annual consumption data was available for all customers. For participants, there were 2,365 customers in the population and 106 customers in the sample with no billing data. For these customers where billing data was not available, the customers were placed into a single stratum, treating them as a simple random sample where all customers have the same weight. Table 6-17 presents the post stratification weights for the participant and non-participant survey results.

**Table 6-17. Participant and non-participant demographic survey analysis post stratification weights**

| Class | Weighting approach | Stratum | Maximum kWh | Population accounts | Total Annual kWh | Sample accounts | Weight |
|---|---|---|---|---|---|---|---|
| Non-participant | Stratified | 1 | 7,205 | 22,795 | 122,224,765 | 1,382 | 16.5 |
| | | 2 | 9,211 | 16,120 | 132,401,385 | 752 | 21.4 |
| | | 3 | 11,194 | 13,614 | 138,177,813 | 616 | 22.1 |
| | | 4 | 13,900 | 11,598 | 143,676,046 | 440 | 26.4 |
| | | 5 | 51,932 | 9,027 | 153,467,607 | 293 | 30.8 |
| Participant | Stratified | 1 | 7,205 | 4,231 | 22,363,096 | 328 | 12.9 |
| | | 2 | 9,338 | 2,945 | 24,291,163 | 207 | 14.2 |
| | | 3 | 11,563 | 2,450 | 25,447,433 | 178 | 13.8 |

| Class | Weighting approach | Stratum | Maximum kWh | Population accounts | Total Annual kWh | Sample accounts | Weight |
|---|---|---|---|---|---|---|---|
| | | **4** | 14,354 | 2,073 | 26,544,537 | 138 | 15.0 |
| | | **5** | 46,435 | 1,606 | 28,339,008 | 132 | 12.2 |
| | **Simple Random** | **1** | | 2,365 | | 106 | 22.3 |

## 6.13 Appendix M: Changes in the home that impact energy use

Respondents were asked to indicate whether they had made any changes in their homes since 2021. Respondents were specifically asked about EV charging, refrigerator use, household size, living area, pool use, spa use, and lighting use which could have an impact on energy use. Respondents could indicate an increase or decrease that would result in increased or decreased energy use. For example, when asked about refrigerator use, respondents could indicate if they were using an additional refrigerator or if they had gotten rid of an additional refrigerator.

Net increase in energy use is estimated as the difference in the proportion reporting an action that would increase energy use and the proportion reporting the opposite action which would decrease energy use. A comparison of participant and non-participant average net increase in energy use from these actions is presented in Table 6-18. Negative percentages reflect answers that indicated a reduction in energy use. For example, a negative percentage for “Using more lighting” indicates that among non-participants, 18% more people said they had been decreasing their lighting use compared to those that said they were increasing it. Among participants 13% more people said they had been decreasing their lighting use. The difference between the two indicates a net increase of 5% of participants increasing their lighting relative to non-participants. The energy consumption increase associated with that increased percentage would reduce the savings estimated by the analysis.

**Table 6-18. Self-reported changes in home impacting net energy use, PY2021**

| Net energy use increasing actions | PY2021 Participants (n=1,089) | PY2021 Non-Participants (n=3,483) | Difference between Participants and Non-Participants | Installation timing factor | Consumption added due to action (kWh) | Aggregate consumption impacts |
|---|---|---|---|---|---|---|
| | a | b | | | | |
| **Added electric vehicle charging to the home** | 0% | 1%a | -1% | 50% | 1,142 | -5.7 |
| **Using an additional refrigerator** | 7% | 8%a | -1% | 50% | 1,093 | -5.5 |
| **Household size increased** | 3% | -2%a | 5% | 50% | 642 | 16.1 |
| **Increased living area/square footage of your home** | 0% | 2%a | -2% | 50% | 642 | -6.4 |
| **Added a spa** | -3% | -5%a | 2% | 50% | 314 | 3.1 |
| **Using more lighting** | -13% | -18%a | 5% | 50% | 64 | 1.6 |

Multiple responses permitted. Negative numbers indicate that the proportion reporting an action that would decrease energy use is greater than the proportion that reports an action that would increase energy use.

Table 6-18 does not include the results of the addition/removal of the pool/pool pump question. The percentages of participant households saying they removed a pool and pool pump represented almost a quarter of the expected share of houses with pools. This is unrealistic and likely reflects a misunderstanding of the question by respondents or a problematic mismatch in the saturation of pools in the two groups. If the pool pump survey results were included, they would add 29.4 kWh of consumption reduction to the participant group. This would indicate that the overall savings estimated by this analysis are over-estimated by 26.2 kWh. This analysis is primarily performed to provide additional confidence that the comparison group is sound and that program savings are not unreasonably underestimated due to known limitations in the methodology. These clearly indicate that participant savings are not underestimated. We do not believe the pool/pool pump results feasibly point to an overestimate of program savings.

There was no consistency in the direction of changes reported by direct install participants and their matched non-participant counterparts.

## 6.14 Appendix N: Surveys

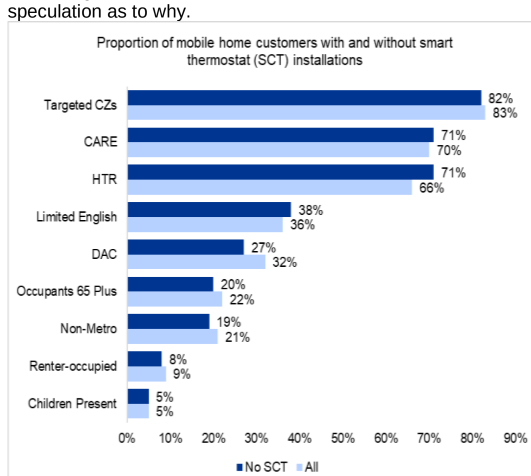
### 6.14.1 Participant survey

The participant survey instrument used in the evaluation is included as a pdf attachment.

### 6.14.2 Non-participant survey

The non-participant survey instrument used in the evaluation is included as a pdf attachment.

## 6.15 Appendix O: Response to comments

| Comment # | Commenter (self-identify by Party, PA, etc.) | Page (as shown in at bottom of pdf document page); or "Overarching" for general comments | Comment/feedback/change requested | Evaluator's Response |
|---|---|---|---|---|
| 1 | SCE | Page 6 | We are not clear on the meaning of "significant portions of the evaluated savings." Does this mean overall residential evaluated savings or direct install savings which seems circular. "Our findings indicate that the programs delivered a small fraction of their claimed savings but were responsible for significant portions of the evaluated savings, indicating that the programs reached population segments that benefited from the programs' EE services. The programs also contributed to peak demand reductions, including during the summer peak hours." | The statement "significant portions of the evaluated savings" is meant to indicate that while the evaluated gross savings are much lower than claimed, the programs were responsible for influencing the evaluated (achieved) level of savings (the evaluated NTGRs of the programs were higher than claimed). We have edited the sentence as follows to clarify this meaning: "Our findings indicate that the programs delivered a small fraction of their claimed savings but were responsible for influencing significant portions of the evaluated or achieved savings, indicating that the programs reached population segments that benefited from the programs' EE services." |
| 2 | SCE | Page 10 | Were the groups with and without smart thermostats pretty similar given this interesting finding: "Smart thermostats are a largely behavioral measure. Among the installed measures, they have the unique potential to have low or even negative savings depending on how they are used. In the current evaluation, mobile homes without smart thermostats in their measure bundle had a whole-home savings of 213 kWh (a gross realization rate of approximately 46%) while those whose installation included a thermostat among their measure bundle had savings of 34 kWh (a gross realization rate of only 6%). | We compared the overall population to the households without smart thermostats (non-SCT) for the composition of the home (the proportion of residents over 65 and under 5 in the two groups), the proportion of customers on CARE, the proportions in DAC and are HTR, and the proportions located in hot climate zones and outside of metro areas. Please see the figure below. The differences are small and point to an unexpected combination of characteristic differences. The non-SCT group has an increased percentage of HTR and limited English households but a decreased percentage of households in DAC. The difference between the two groups is greater than these numbers because here we are comparing no SCT to overall percentages. If these differences are meaningful with respect to the savings difference, which is not assured, we do not have any speculation as to why.<br><br> |
| 3 | SCE | Comment | Does the evaluation team have implications for upcoming or existing Third Party programs with this or similar measures? | The findings and the recommendations DNV provided will be relevant for residential programs that deliver similar measures through direct install delivery mechanisms and claim savings using the same DEER values. |

| Comment # | Commenter (self-identify by Party, PA, etc.) | Page (as shown in at bottom of pdf document page); or "Overarching" for general comments | Comment/feedback/change requested | Evaluator's Response |
|---|---|---|---|---|
| 4 | SCE | Slide 41 | Regarding participant satisfaction with "energy savings and cost reduction," is this program element referring to participant satisfaction with the energy savings and cost reduction they received as a result of participating in the program, or, the energy savings and cost reduction they expected to see based on information Synergy shared with them? | The program element is referring to satisfaction with the respondents' perceived energy and cost reductions as a result of participating in the program. |
| 5 | SCE | Slide 51/ Report P. 69 | Could you elaborate a bit more on the context behind the suggestion that "programs consider improved customer/contractor training when installing smart thermostats in direct install programs"? Is the driver for this suggestion based on inadequate or unsatisfactory work performed by the technician when installing the smart thermostat? Or is the driver a lack of customer education/information when the installation is performed? | As shown in Table 4-13, both lack of education/instruction by installers and installation issues are reasons for customer dissatisfaction. The table provided some of the verbatim responses provided by customers and the responses indicated that customers need to be educated on how to use the smart thermostat and that installers in the field did not always provide the needed instructions. Additional contractor training so contractors educate customers on the optimal use of smart thermostats to maximize the benefits from the measure would be useful. The responses also indicated that some customers experienced installation issues; for example, one respondent indicated that the installer "didn't hook my thermostat to WI-FI and didn't tell me I needed to do it. I called Honeywell when I couldn't change the time and they walked me through the procedure." |
| 6 | SCE | Slide 54/Report P. 42, 69 | Based on measure package requirements, faucet aerators are only installed in homes that use electric water heating, and, if a customer has an existing low flow aerator, the program does not replace it with a new one. | As we indicated in the report and during the stakeholder presentation in March 2023, DNV did not do site visits and is not reporting that the programs replaced existing low-flow aerators. The report only provided possible reasons for the observed aerator savings that are lower than claimed. It is possible that saving for this measure is lower than claimed because the change in flow rate is less than assumed in the measure package or the flow is uncertain. We have updated the recommendation to include this explanation. |
| 7 | SCG | Section 1.3, p. 8 | Please discuss the program vs. measure focus advantages and disadvantages. Would evaluation team include a hybrid approach recommendation? | Measure-focused evaluations are typically designed to address the unit savings, NTG, and other important measure-related parameters while program-focused evaluations address overall program savings and performance. The purpose of an evaluation will drive the type of analysis and focus required. Future evaluations will need to design approaches that align with their purpose. |
| 8 | SCG | Table 1-3, p. 9 | Expected water aerator gas savings. How did the evaluators make sure there is no gas heaters in sample? | SCE ran the program and did not claim gas savings. As a result, DNV evaluated only claimed electric savings. We verified the installation of measures including aerators but not the fuel type for water heaters. In a comment to the report, SCE indicated that "Based on measure package requirements, faucet aerators are only installed in homes that use electric water heating." We have added a footnote to indicate that future studies of this type should consider verifying water-heating fuels used in customer homes. |
| 9 | SCG | Table 1-7, p. 16 | Please specify measures needing more education (e.g., smart thermostats) | In general, customers had lower-than-expected levels of awareness about the measures they received. Survey responses to verify installed measures indicated that many customers did not know all the measures that they received through the two programs DNV evaluated. Thus, a starting point for programs such as the ones that delivered the Res DI measures would be to provide adequate information on installed measures so customers are aware of the benefits the programs provide. Besides this, programs should focus more attention on providing education about the optimal use of measures that have a behavioral component, including how to operate the technology to maximize both comfort and energy savings. |
| 10 | SCG | Section 2.1, p. 17 | Please add ancillary gas benefits. | Section 2.1, p.18 of the report provides both gas and electric savings the Res DI programs expected to deliver. Table 2-2 indicates that the programs expected to provide gas benefits in the form of therm savings from installed smart thermostats and duct sealing. The figure below this table (Figure 2-1) indicates the proportion of gas benefits/savings the programs expected from the two installed measures. |

| Comment # | Commenter (self-identify by Party, PA, etc.) | Page (as shown in at bottom of pdf document page); or "Overarching" for general comments | Comment/feedback/change requested | Evaluator's Response |
|---|---|---|---|---|
| 11 | SCG | Table 2.1, p.18 | No SingleFamily aerators / showerheads, and manufactured homes may have electric water heaters primarily. Please point to this or other reasons for no gas aerator savings. | See response to comment #8. |
| 12 | SCG | Section 3.3.2, p. 27 | Participants and nonparticipants customers may have had programmable thermostats and not thought of it as smart thermostats but that delivered similar same savings. Some thermostats like Lux (Smart Thermostat) have preprogrammed settings and achieve savings. Please discuss how this issue may be considered in the future (or was in this study). | The PY2021 Res DI programs installed mostly Nest, Ecobee, and Honeywell brands. However, past residential direct install programs included the Lux brand as part of their smart thermostat offering. In other words, Lux is a smart thermostat. Smart thermostats have features that not programmable thermostats do not have, including internet connectivity that allows them to sense occupancy and adjust setpoints, and take advantage of manufacturer algorithms to save energy. We should also note that DNV, as in past years, surveyed non-participants for the presence of smart thermostats in their homes and adjusted participant smart thermostats savings (upwards) based on this information. Additional details on the adjustment of smart thermostat savings for the presence of smart thermostats among non-participants are provided in Section 6.7.2 of the report. |
| 13 | SCG | Section 3.3.4, p. 29 | With assumptions made in eQuest, the distribution across measures may limit the applicability of recommendations to specific measures. Please discuss this aspect. | While the distribution across measures provided by eQuest is the starting point, the statistically adjusted engineering regression methodology is specifically designed to adjust those starting points to reflect the underlying data, given the observed savings at each site with its specific mix of measures. As is evident from the report, final savings estimates are quite different from initial allocations. For this reason, the measure level estimates are as accurate as possible in multi-measure programs with variable measure bundles. The measure savings estimates will reflect the overall program installation, measure bundle mix, population, etc. |
| 14 | SCG | Section 4.2.5.1.2 | Did the evaluators consider a recommendation to look at DHW algorithms? | DNV indicated that possible explanations for the low aerator realization rates are inflated unit energy savings due to inaccurate assumptions in the deemed measure package or changes in flow rate that are less than assumed or uncertain and recommended that these "require(s) investigation and correction if necessary." |
| 15 | SCG | Table 4-13, p. 55 | Can recommendations included a focus on smart thermostat education and technology selection (specific Thermostats cited as good / some as less effective)? | DNV recommended, "follow up to ensure installed equipment works as intended and (for programs to) provide better education and information to enable customers to receive the full benefits of the installations." While this recommendation is for all measures including smart thermostats, we have edited the recommendation to include the phrase "particularly for measures with behavioral aspects." Recommending a smart thermostat brand that is more effective than others is beyond the scope of the current study. |
| 16 | SCG | Section 4.6.3, p. 64 | The section discussed expanding wall and ceiling installation, can this and other new measures be added as a recommendation for the Direct Install programs? | The insulation measures complement HVAC measures, and our survey findings indicate opportunities exist to serve customers by providing these measures. While these indicate the potential benefits possible from the insulation measures that programs can use to make decisions on future program offerings, a study focused on these measures will be needed for DNV to recommend their inclusion in future program offerings. |
| 17 | SCG | Section 6.14, p. 87 | Please provide Surveys (no attachments were provided). | Noted. Survey instruments have been included in the current posting. |
| 18 | SDG&E | 69-70 | Conclusion and Recommendations start with "11" vs. "1". Recommend updating appropriate count order. | Noted. Edits made. |

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