**`Work Paper SCE17HC054**

**Revision 1**

**Southern California Edison**

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**Residential Smart Thermostat**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | See section 1.1 |
| **Measure Description** | Residential Smart Thermostat |
| **Base Case Description** | A combination of programmed Setback Programmable Thermostats and Non-Programmable Thermostats (or not programmed setback thermostats) |
| **Units** | Household (1 Smart Thermostat per household) |
| **Energy Savings** | Refer to Attachment 1 |
| **Full Measure Cost ($/unit)** | $209.31 |
| **Incremental Measure Cost ($/unit)** | $142.46 |
| **Effective Useful Life** | HV-ProgTstat: 9.1 years (Non-DEER) |
| **Measure Installation Type** | Normal Replacement (NR) |
| **Net-to-Gross Ratio** | 0.55 (Res-Default>2) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 2/17/2017 | SCE/CalTF | New work paper, first version |
| 1  Resubmission | 2/8/2019  5/31/2019 | TRC with direct guidance and management from Andres Fergadiotti/SCE, in full collaboration/coordination with PGE, SCG, and SDGE | * New calculation template for 2019 program year * Baseline technologies updated based on PG&E’s Smart Thermostat Program Process Evaluation * Updated technical description and code sections * Updated installation type to include only Normal Replacement (NR) * Added mid-Stream and up-Stream delivery and incentive methods * Net-to-gross ratio updated based on PG&E’s Smart Thermostat Program Process Evaluation * Effective use life updated based on SCE’s 2019 “EUL Analysis of Residential Smart Communicating Thermostat—Vendor A and B” study * Calculation methodology and savings updated based on PGE’s Smart Thermostat Study (Year 1). * IMC updated to reflect 2019 cost analysis. * Added measure savings estimates for technology controlling Heat Pump equipment * Added solution code for heat pump * Removed mid-stream and up-stream delivery and incentive methods. * Electric cooling savings adjusted using DEER-Weighted Tstat Schedules. * Electric heating savings removed for the heat pump measure. * For MFM, the adjustment (scaling) factor was improved using System Capacity (ton) documentation from Programs. * Added Sections 1.6.2 Heat Pump Heating (Electric) Savings, 1.6.3 DEER2020 Peak Demand Reduction, and 1.6.4 Effective Useful Life under Future Data Needs |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |

Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

A **Smart Thermostat** is a device that controls heating, ventilation, and air-conditioning (HVAC) equipment to regulate the temperature of the room or space in which it is installed, has the ability to make automated adjustments to the set point of the HVAC system to drive energy savings (electric and gas), and has the ability to communicate with sources external to the HVAC system. For connection, the Smart Thermostat may rely on a home area network (e.g. Wi-Fi) and an internet connection that is independent of the Smart Thermostat.[[1]](#footnote-1)

This work paper estimates the household (per household) heating and cooling energy savings from the installation of a Smart Thermostat in the residential households. The calculation approach utilized in this workpaper takes in account the range in energy savings change associated with smart thermostat installations, and the results represent an average savings of the technology by the climate zone based on referenced studies and/or evaluations.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Residential Smart Thermostat with two-way communication and automatic scheduling capabilities |
| Base Case | Setback Programmable Thermostats and Non-Programmable Thermostats |

**Measures and Codes**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| TBD | TBD | CE-18623 | TBD | Residential Smart Thermostat |
| TBD | TBD | CE-20995 | TBD | Residential Smart Thermostat Heat Pump |

**Baseline Characterization**

Baseline characterization for this measure is being informed by PGE’s Smart Thermostat Program Process Evaluation (Evaluation) Report [Attachment 5]. The Evaluation draws on participant surveys conducted between October 2017 and February 2018 on their experience with the program including their motivation for participation, thermostat installation and use, the influence of the program on their purchase decision, satisfaction, and housing characteristics including existing baseline conditions on thermostat type controlling their corresponding HVAC equipment. The following table describes base case technology characterization as informed by referenced study – See Attachment 5 for details.

**Base Case Technology Characterization**

|  |  |
| --- | --- |
| **Thermostat Type** | **Adjusted Survey Population of Thermostats** |
| Manual Thermostat | 11% |
| Programmable Thermostat | 76% |
| Smart Thermostat | 6% (Non-qualifying customers) |
| Other / Unknown | 7% |

**General Eligibility Requirements**[[2]](#footnote-2)

1. PA shall employ QA/QC procedures to ensure that the thermostat is installed in an eligible home and is attached to the type of HVAC equipment that is being incentivized, whether it is for natural gas or electricity savings.
2. PA shall confirm that the customer has a newly purchased smart thermostat. At minimum, the PA shall obtain a copy of the thermostat sales receipt and the PA shall confirm the purchase date is on or after the program’s start date.
3. Customer eligibility shall be determined by each PA prior paying and/or approving rebate. Upon request, all data associated with determining eligibility shall be provided to Energy Division. PAs shall extend this requirement to any third party vendors who assist PAs with determining customer eligibility and to the extent that they are used to determine eligibility, data regarding dates of purchase, location of home, customer HVAC equipment, etc.

**Device Eligibility Requirements**:

* Smart thermostat must be in full compliance with ENERGYSTAR program requirements and product specification for Connected Thermostats products Version 1 or later.

**Customer Eligibility Requirements:**

* Customer segment: Residential
* Must use the thermostat to control a fully functional heating and/or cooling equipment supplied by fuels provided by the utility paying the end-customer incentive
  + For single-fuel utilities (or dual-fuel utilities in a portion of their service area where they only supply one fuel), only savings for the applicable delivered fuel may be claimed
  + Eligible heating equipment: gas forced-air furnace, electric forced-air furnace, and heat pump
  + Eligible cooling equipment: central air conditioning and central heat pump

For SCE, heat pump central qualifying HVAC equipment is incentivized under solution code CE-20995, whereas all non-heat pump central qualifying HVAC equipment is incentivized under solution code CE-18623.

**Implementation and Installation Requirements:**

* **Climate Zones:** All 16 California Climate Zones are eligible (no cooling savings defined for Climate Zone 1)
* **Building Types:** Residential Building Types - SFm, MFM, and DMO

## 1.2 Technical Description

A Smart Thermostat is a device that controls heating, ventilation, and air-conditioning (HVAC) equipment to regulate the temperature of the room or space in which it is installed and has the ability to make automated adjustments to the set point of the HVAC system based on occupancy data, weather data, and HVAC performance data (or some of this data) or combination of these parameters to optimize heating and cooling around occupancy and/or HVAC equipment operation.

Smart Thermostat technology participating in Energy Efficiency Utility programs shall be in full compliance with latest ENERGYSTAR Program Requirements Product Specification for Connected Thermostat Products and associated Qualifying Product List, including but not limited to product capabilities and/or features that may be enabled through the device, service, or any combination of the two while maintaining (and with persistency of) these capabilities through subsequent firmware and software changes.

## 1.3 Installation Types and Delivery Mechanisms

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Normal Replacement (NR) | Industry Standard Practice | N/A | EUL | N/A |

Measure application type is characterized as Normal Replacement (NR). Given that (a) Evaluation [Attachment 5] determined that vast majority of thermostats under the existing condition consist of programmable thermostats (76%) followed by manual thermostats (11%) and (b) the average Home Vintage characterization from participating customers is expected to average years 2001-2003, with most of the programmable (and/or manual) thermostat technology expected to have already reached out its useful life; hence, a NR measure application type designation is determined appropriate.

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Downstream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized.   1. **Downstream Energy efficiency rebate (no demand response)**    * Customer must purchase and install a qualifying product to receive an energy efficiency (EE) rebate    * Customer who purchase qualifying product but choose not to join a demand response (DR) program, may still receive a rebate.    * Applicable utilities: SDG&E, SCE, SoCal Gas and PG&E. 2. **Downstream Energy efficiency rebate with DR rebate (or incentive) to encourage IDSM**    * Customer must purchase and install a qualifying product to receive the EE rebate    * Additional DR rebate or incentive may be provided to the customer if they choose to enroll in a DR program after installing their new device.    * Applicable utilities: SDG&E, SCE, SoCal Gas and PG&E. |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. Direct install program also may have a co-pay. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

**DEER Difference Summary**

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | Yes |
| DEER Measure Case | No |
| DEER Building Types | Yes |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | Yes |
| DEER Version | - |
| Reason for Deviation from DEER | The DEER 2019/2020 database does not support measure evaluation on Smart Thermostat technology. |
| DEER Measure IDs Used | - |

Note that baseline energy consumption for all Residential building types (SFM, MFM, and DMO) under the measure savings evaluation were enabled using latest DEER Residential prototypes from CPUC’s MASControl3 software application under the following assumptions: All 16 Climates Zones; Median Vintage - 2007; Central HVAC with Gas Furnace <45kBtuh; SEER14; AFUE 0.80; All DEER T-Stats (Weighted); and CTZ2010 weather.

As part of the resubmission of SCE17HC054 Rev1, the measure savings (specifically the baseline energy consumption) were adjusted for all Residential building types using All DEER Thermostat schedules and DEER Weighted to better align with generally used ex-ante procedures. See Attachment 2.

### 1.4.2 Net-to-Gross Ratio

The Net-to-Gross (NTG) Ratio for this measure assumes a DEER’s Residential default NTG of 0.55. This assumption is informed by The Evaluation [Attachment 5] providing program’s influence on customers when purchasing this technology. To assess the influence on participants’ purchase decisions, this evaluation included specific questions to customers to understand if they had considered a smart thermostat before hearing about the program; their likelihood to have purchased a smart thermostat without the rebate; and when they would have made the purchase if the rebate was not available. Customer’s feedback suggests the following regarding program influence on the measure:

* **High Likelihood of Being a Free Rider**: 27% of respondents were planning on purchasing a smart thermostat around the same time.
* **Moderately Likelihood of Being a Free Rider**: 26% of respondents were somewhat likely or would have purchased in the future.
* **Low Likelihood of Being a Free Rider**: About half (47%) of participants are not likely to be free riders, had not previously considered, were not likely, or would never have purchased.

Hence, the evaluation suggests that about 47% of participants were influenced by the program, whereas 26% of the participants were possibly influenced by the program. These results are aligned with the 0.55 Residential Default NTG. Therefore, the NTG used for this workpaper update is the “Res-Default>2.”

The NTG value is obtained using the DEER READI tool v.2.5.1.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **Bldg Type** | **Measure Delivery** | **NTGR** |
| Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Res | Any | Any | 0.55 |

### 1.4.3 Spillage Rate

Spillage rates are not tracked in workpapers; they are tracked in an external document which will be supplied to the Commission Staff.

### 1.4.4 Installation Rate

The IR values were obtained using the DEER READI tool v.2.5.1. The relevant IR values for the measures in this work paper are in the table below.

**Gross Savings Installation Adjustment Rate**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **Bldg Type** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

### 1.4.5 Effective Useful Life

Effective Useful Life (EUL) for smart thermostats is not available in DEER.

An EUL is an estimate of the median number of years that measures installed under the program remain in place, operating and providing savings.3 EUL values are employed with CPUC authorized annual avoided costs and measure‐specific energy savings to determine lifecycle dollar benefits associated with a measure.

**Effective Useful Life Evaluation Protocol**

Per California’s Energy Efficiency Evaluation Protocols, there are two allowable methods for EUL analysis: basic rigor and enhanced rigor.[[3]](#footnote-3) Both methods require survival analysis or other analysis methods that specifically control for right-censored data. Right-censored data are failures that might take place after data collection.

Sample size requirements should be determined using power analysis, results from prior studies on similar programs, and professional judgments. A power analysis to determine the required sample size must be calculated by setting power to at least at 0.7 for basic rigor and to 0.8 for enhanced rigor to determine the sample size required at a 90% confidence level (alpha set at 0.10).

**Effective Useful Life Analysis and Results**

Using non-parametric Kaplan-Meier estimation methodology in R statistical software, a survival analysis was used on data provided by two main smart thermostat vendors. Specifically, a survival analysis method was used on the thermostat connectivity data to account for right censorship in the data and to provide unbiased estimates of survival functions and rates.

The EUL analysis combined non-linear and linear results to quantify the uncertainty around the EUL estimates, which assisted with program implementation data, results on a weighted average value of 9.1 years.

Attachment 9 (CONFIDENTIAL) provides the full background and additional details including analysis limitations and recommendations on the EUL analysis and results supported by the IOUs as part of this workpaper update.

**Effective Useful Life**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **Use Category** | **Life** | |
| 1st Baseline | 2nd Baseline |
| HV-ProgTstat | Smart Thermostat | Res | HVAC | 9.1 (Non-DEER) | N/A |

### 1.4.6 Codes and Standards Analysis

Thermostats fall under the jurisdiction of Title 24 as listed in the Table below.

**Code Summary**

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 20 (2018) | N/A | N/A |
| Title 24 (2016) | N/A | January 1, 2017 |

**Title 20:** This measure does not fall under Title 20 of the California Code of Regulations [515]

**Title 24:** Thermostats do fall under Title 24 of the California Code of Regulations, but smart thermostats discussed in this work paper are not a subject to this requirement [496].

**Federal Standards:** These measures do not fall under Federal DOE or EPA Energy Regulations.

Note that the applicable codes and standards dictate only that the thermostats be capable of shutting systems off and adjusting temperature set points during unoccupied hours. There are no requirements to actually shut down systems during unoccupied hours, or to make any specific unoccupied temperature set point adjustments.

## 1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

Latest relevant Utility supported smart thermostat studies leveraged to support measure impacts are documented herein. These studies support the adequate experimental methods and supporting documentation for evaluation of the measure.

### 1.5.1 PG&E Smart Thermostat Study: First Year Findings

PG&E designed the Smart Thermostat Study (Study) as an Emerging Technologies Program scaled field placement to gather data from customer homes that have been randomly assigned to receive a free smart thermostat. The Study is a randomized encouragement design (RED) trial in which several thousand homes were randomly assigned to the encouraged group, all of whom were offered a free, directly-installed smart thermostat, and two thousand similar homes were randomly assigned to a control group, none of whom were offered a thermostat. Three different brands of thermostats were tested in the study; the goal was to install 1,000 of each type of thermostat in participants’ homes. See Attachment 6 for details. **Note that the regression models used in the analysis of this workpaper are modified from those published in the ET Report. See Section 2 for the details on the revised calculation methodology.**

### 1.5.2 PG&E Smart Thermostat Study: Second Year Findings

This addendum to PGE’s First Year Findings provides energy savings results from the second year of monitoring as well as the results of an “end-of-project” survey of both the treated and untreated/control group participants, conducted in November 2017. The findings of this study suggest persistent electric savings for all three brands of thermostats and persistent natural gas savings during the heating season for one of the evaluated thermostats. See Attachment 7 for details. **Note that this Study was evaluated but not included in the final evaluation of measure savings**. See Attachment 8 on reasoning for its exclusion.

### 1.5.3 PG&E Smart Thermostat Program Process Evaluation – Opinion Dynamics

This process evaluation draws on participant surveys conducted between October 2017 and February 2018. Participants provided feedback on their experience with the program including their motivation for participation, thermostat installation and use, the influence of the program on their purchase decision, satisfaction, and housing characteristics. See Attachment 5 for details.

### 1.5.4 SCE Replication and Improvement of Smart Thermostat EUL

This study evaluated effective useful life (EUL) of smart thermostat technology with two-way communication and automatic scheduling capabilities. The analysis, leveraging data sets from leading SCT manufacturers in California, was conducted using the appropriate survival functions, in compliance with California EUL Analysis Protocol. See Attachment 9 for details.

## 1.6 Data Quality and Future Data Needs

**1.6.1 Heating (Gas) Savings**

IOU independent studies are needed to support measure savings potentials of technology controlling HVAC space (gas) heating. Currently, there are ongoing efforts from the IOUs for supporting evaluation of heating (gas) savings which will be available in the future for supporting updates to the workpaper.

**1.6.2 Heat Pump Heating (Electric) Savings**

Per “Disposition for the Smart Communicating Thermostat SCE17HCO54 Rev 1 Workpaper”, energy savings from heat pump heating reductions require additional study to demonstrate verifiable savings. Future efforts should be explored to support EM&V studies on technology controlling Heat Pump equipment.

**1.6.3 DEER2020 Peak Demand Reduction**

The current savings methodology (including monthly AMI data for the treatment group) is not satisfactory to properly evaluate coincident peak demand reductions from this technology.

**1.6.4 Effective Useful Life**

SCE conducted an Effective Useful Life study with CADMUS, which resulted with a weighted average value of 9.1 years [Attachment 9]. Future research should address savings persistence and expand the survival analysis to include additional years of data applying appropriate survival analysis techniques per the CA Energy Efficiency Evaluation Protocols

# Section 2. Calculation Methodology

## 2.1 General Methods (HVAC Cooling)

Measure savings on HVAC cooling energy were estimated based on PGE’s Year 1 study. PGE’s Year 2 study was evaluated but not directly included in final calculation approach/methods given abnormalities further described in this Section. These studies were designed using a Randomized Encouragement Design (RED). A RED design is an appropriate alternative to a Randomized Control Trial (RCT), when it is known that not all the treatment customers will accept the treatment, i.e., when treatment is voluntary.

Energy savings were estimated by first using a statistical difference-in-differences (DID) approach, and second, using a fixed-effect regression approach. This two-step process allowed preliminary estimates of savings that are unconstrained by the assumptions of a regression model. Then, those estimates were refined using a regression approach.

As part of the statistical DID, the method compares the monthly usage of the encouraged customers to the randomly assigned control group customers, both during the participation period (treatment period) and for a time before participation started (pretreatment period). Comparison during the treatment period gives an unadjusted estimate of the impacts. This estimate is then corrected using the difference during the pretreatment period to adjust for any preexisting differences between the encouraged and control groups.

In the second step of the analysis, savings were estimated using regression models in which energy use is evaluated as a function of other explanatory variables (e.g., weather) that the statistical DID is unable to do. The models include the encouraged and control customers in both the treatment and pre-treatment periods.

**APPROACH**

The approach to developing statewide ex-ante estimate based on PG&E’s Year 1 Smart Thermostat Study results is described below. First, modifications to the ex-post models and associated rationale are described, followed by a description of the final ex-ante model and finally, the actual extrapolation approach and results.

**MODIFICATIONS TO THE EX-POST MODELS**

The regression models that were developed for the original analysis were developed with several goals in mind:

* Estimating ex-post impacts for three different thermostats, while accounting for the RED design.
* Attaining reasonable comparison between the statistical Difference in Difference (DID) and the regression output.
* Estimating monthly impacts with a primary focus on summer savings for electric customers.

The original ex-post analysis goals do not align with the goals of an annual ex-ante estimate. Through collaboration with the CPUC’s ex-ante contractor, EM&V consultant understands the goals of the ex-ante analysis to be as follows:

* Develop a model that is appropriate for extrapolation to weather conditions outside of what participants experienced.
* Attain a single estimate for smart thermostats that is representative of the types of thermostats that PG&E customers are installing, rather than three separate estimates.
* Develop a normalized annual estimate of savings without focusing on a specific season.

**UPDATED EX-ANTE MODEL**

Based on the ex-ante analysis goals, EM&V consultant collaborated with ex ante review consultants to develop an updated model that is appropriate for an ex-ante estimate. EM&V consultant also updated the analysis to estimate the annual savings directly rather than estimate savings at a monthly level. The updated model has the following characteristics:

* The model maintains the full structure of the DID and weather elements regardless of significance, which provides more stability for the estimates during extrapolation.
* The model employs a fixed effect approach.
* The model estimates the overall effect of the two thermostats with highest participation of PGE’s program making up over 97% of PG&E’s current rebates jointly.

The final ex ante model specification is below:

where:

= the kWh consumption of customer in month

= a fixed effect for each customer

= an indicator that takes on a value of for each customer when month is in the treatment period

= an indicator which takes on a value of customer is in the encouraged group

= total cooling degrees for customer in month

= total heating degrees for customer in month

= the error for customer in month

**EXTRAPOLATION**

Before describing the actual approach, several considerations are provided below which are important context for the estimates.

**Important Considerations**

In determining the most appropriate methodology for the ex-ante estimates of savings, the following is considered:

* The PG&E Year 1 Study was not designed to be representative of all Californians.
* The PG&E Year 1 Study model was estimated using actual CDD and HDD from PG&E’s 23 weather stations, not CEC climate zone data.
* The results do not represent weather normal impacts, but actual ex-post impacts.
* Impacts from participants in PG&E hottest zones may not be representative of all CA customers, i.e. the weather relationships estimated by the ex-ante regression model may not be applicable across the entire state.
* In the second year of the study (Year 2) we noted the following anomalies compared to the first year (Year 1):
  + The study participants experienced weather that was quite different with a more extreme summer.
  + The samples eroded due to move outs and other account changes. The shrinking samples made the encouraged effect even harder to detect.
  + Based on conducted survey, both control group customers and encouraged customers began installing smart thermostats, nearly 15% of each group installed thermostats independent of the program.
  + The savings patterns seemed to shift, with more savings being seen in the spring (and even winter) and less savings in the summer. These shifts in savings trends seemed counterintuitive.

Given the considerations outlined above, and the remaining timeframe for completing the analysis, it was determined that a simple straightforward approach which makes minimal additional assumptions based on the model parameters is the most appropriate.

At a high level the proposed approach is as follows:

1. Estimate the average HVAC cooling + fan energy consumption for a single family home in each of CA’s 16 climate zones using the SFM DEER prototypes.
2. Generate a single annual savings estimate from the ex-ante model using Year 1 Study data only. Year 2 Study data was evaluated but not directly included in final analysis due to the anomalies outlined above.
3. Use the ex-ante model to estimate the annual HVAC cooling baseline for the encouraged group and estimate the percent impact. When using the ex-ante model, the HVAC cooling baseline represents the ex-ante model’s estimate of weather responsive load based on the relationship between CDD and kWh.
4. Apply the percent impact from step 2 to the HVAC cooling + fan energy consumption for a single family home with Central Air Conditioning (CAC) in each of California’s 16 climate zones based on the SFm DEER prototype.

The approach is described in more detail below:

**1. Estimate the average HVAC cooling + fan energy consumption using the DEER prototypes.**

This was done by enabling latest SFm DEER prototype using the MASControl3 software application under the following assumptions: All 16 Climates Zones; Median Vintage - 2007; Central HVAC with Gas Furnace <45kBtuh; SEER14; AFUE 0.80; DEER weighted Thermostat Schedules; and CTZ2010 weather.

**2. Use ex-ante model to generate an annual savings estimate.**

The ex-ante model was used to estimate the annual savings attributable to the smart thermostats. To do this, the savings were estimated as a linear combination of the following parameters from the ex-ante model:

This estimate represents the annual savings for the encouraged group. A weighted acceptance rate was used to estimate the savings of the treated group under the RED.

**3. Use the ex-ante model to estimate an annual cooling baseline load and percent impact.**

The HVAC cooling baseline load was then estimated for the encouraged group. This represents the ex-ante model’s estimate of weather responsive load absent the thermostat based on the estimated relationship between CDD and kWh. To estimate the cooling baseline load, we use the following linear combination of variables from the ex-ante model:

The annual savings estimate in percent terms was calculated by dividing the annual savings by the cooling baseline. The percentage impacts are reflective of how pilot participants responded to the treatment but using percentages allows us to scale the impacts to represent PG&E participants in each climate zone.

4. **Apply percentage impacts to DEER HVAC + fan cooling consumption estimates for each CEC climate zone to estimate impacts**

The final step in the analysis is to apply the annual percentage savings from the ex-ante model to the HVAC + fan cooling consumption for an average single family home with CAC in each of California’s 16 climate zones as estimated by the appropriate SFm DEER prototype. This provides an estimate of how other Californians would respond to the thermostats assuming they would respond similarly to PG&E’s program participants.

One key advantage of the proposed approach is that it does not require applying parameter estimates (relationships) across very different climate zones (inland vs. coastal vs. desert) which would in turn would assume that all customers have the same relationship with weather regardless of their climate. It does, however, assume that all customers in the state would have a response that would be similar to those that participated in the pilot.

**RESULTS**

The results of the extrapolation analysis are presented in this section. The ex-ante model output is presented first, followed by the cooling baseline and finally the savings estimates.

**Ex-ante Model output**

The figure below presents the output of the updated ex-ante model from Stata. As with any standard modeling output the parameter estimates are presented on the left and the associated statistics on the right. It should be noted that Stata does not output a typical r-squared value. However, the “within” r-squared is analogous to an r-squared from a regular OLS model (without fixed effects) and the statistic *rho* represents the total fraction of variation captured by the fixed effects.

***Ex-Ante Model Output***



**Ex-Ante Cooling Baseline Estimates vs. DEER HVAC + fan Cooling Baseline Estimates**

In this section, the HVAC cooling baseline estimate is presented from the ex-ante model, followed by the SFm DEER HVAC + fan cooling baseline estimates, and finally, a comparison of the two.

The table below presents the ex-ante model’s estimate of the total baseline and the cooling baseline. The ex-ante cooling baseline is also presented as a percent of the total. The model estimates that the cooling load makes up between 3 and 48 percent of the total baseline load depending on the month of the year. The overall pattern makes sense given what is known about the climate zones included in the pilot, with the hottest months of the year occurring in the mid-summer months of July and August.

See Attachment 8 for details on calculation methods.

**Ex Ante Savings Estimates**

The ex-ante model’s estimate of the savings as a percent of the ex-ante cooling baseline results in savings that make up about 11% percent of the total HVAC cooling baseline at an annual level. Refer to Attachments 2 and 8 for details on calculation methods and results.

The table below documents the ex-ante impact for each climate zone. The impact is calculated by applying the 11% impact predicted by the model to the annual cooling load in each zone. The nominal impact (kWh) and the impact as a percent of the total annual load are presented below.

**Ex-Ante Impact for Each Climate Zone for SFM**

|  |  |  |
| --- | --- | --- |
| **Climate Zone** | **% Savings Contribution**  **(SFM HVAC Cooling Energy)** | **Impact (kWh)**  **SFM** |
| CZ01 | 11.0% | 0.0 |
| CZ02 | 11.0% | 53.0 |
| CZ03 | 11.0% | 14.4 |
| CZ04 | 11.0% | 72.5 |
| CZ05 | 11.0% | 7.8 |
| CZ06 | 11.0% | 63.2 |
| CZ07 | 11.0% | 72.9 |
| CZ08 | 11.0% | 155.1 |
| CZ09 | 11.0% | 142.2 |
| CZ10 | 11.0% | 171.7 |
| CZ11 | 11.0% | 189.6 |
| CZ12 | 11.0% | 110.1 |
| CZ13 | 11.0% | 215.6 |
| CZ14 | 11.0% | 408.1 |
| CZ15 | 11.0% | 503.2 |
| CZ16 | 11.0% | 27.3 |

Refer to Attachments 2 and 8 for details on calculation methods and results. Please note that Ex-Ante input models and hourly data reports will be provided on request.

## 2.2 Measure Savings Scaling for MFM and DMO (HVAC Cooling)

Given that PGE’s Year 1 and Year 2 Studies exclude evaluation of measure savings for MFm and DMo, scaling (energy savings) factors were estimated for MFm and DMo. These were determined using the latest DEER2020 HVAC Upgrade measures based on the ratio of the normalized energy impacts (e.g., kWh/Ton) compared to SFm.

Estimated adjustment factors vary by climate zone. However, no direct correlation was observed between the adjustment factors and CZs as there are several intricate factors varying among the climate zones that determine the energy impacts.

Further adjustments were applied to the MFm scaling factor to account for variation in system capacity between the MFm DEER models and system capacity seen by the program. This analysis was conducted using the DEER MFm prototype adjusted from 1.0 ton (DEER defaulted - average per dwelling) to 2.0 tons (program informed average capacity per dwelling).

**Adjustment Factors for DMo and MFm**

|  |  |  |
| --- | --- | --- |
| **Climate**  **Zone** | **Adjustment Factor for DMO** | **Adjustment Factor for MFM** |
| CZ01 | 0.46 | 0.96 |
| CZ02 | 0.86 | 0.79 |
| CZ03 | 0.87 | 0.72 |
| CZ04 | 0.88 | 0.95 |
| CZ05 | 0.94 | 0.57 |
| CZ06 | 1.40 | 0.85 |
| CZ07 | 0.74 | 1.02 |
| CZ08 | 0.97 | 0.84 |
| CZ09 | 0.97 | 0.98 |
| CZ10 | 1.06 | 0.72 |
| CZ11 | 1.31 | 1.53 |
| CZ12 | 1.25 | 1.31 |
| CZ13 | 1.13 | 1.29 |
| CZ14 | 0.77 | 1.18 |
| CZ15 | 1.24 | 1.23 |
| CZ16 | 1.89 | 1.53 |

Attachment 4 and 13 detail methodology and procedures used for estimating these scaling factors.

As with SCE17HC054 Rev 0, no peak demand reductions are included in this workpaper.

## 2.3 General Methods (HVAC Heating)

Measure savings potential on heating (gas) in this version of the workpaper retains the gas impacts from the previous workpaper SCE17HC054 Rev 0 until an additional gas impact evaluation is conducted for revised savings potentials.

The energy impact analysis in SCE17HC054 Rev 0 used a fixed effects regression model and the heating setpoint data from SCT units collected by a manufacturer. The second baseline heating savings from this analysis for 16 climate zones in single-family building provide the basis for approximating gas savings potentials in MFm and DMo. The latest Residential DEER prototypes with baseline heating consumption, shown in below table, is utilized to calculate adjustment factors and derive gas impacts for MFm and DMo building types.

**Adjustment Factors for Heating Savings using DEER Prototype Heating Consumptions (CZ09)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Building Type** | **Annual Heating Energy**  **(Btu x 106) [1]** | **Annual Heating Energy**  **(Therms)** | **Annual Heating per System**  **(Therms)** | **Adjustment Factor** | **Savings Contribution** |
| SFM | 49.4 | 494.0 | 123.5 | 100.0% | 8.9% |
| MFm | 108.9 | 1,089.2 | 38.9 | 31.5% | 8.9% |
| DMo | 17.7 | 177.2 | 88.6 | 71.7% | 8.9% |

[1] Space Heating from MC3 annual consumption summary

Measure’s consolidated Annual Energy Savings for SFM, MFm and DMo are tabulated in Attachment 2.

# Section 3. Calculation Methodology

# SCT Controlling Heat Pump Equipment

## 3.0 General Methods

Measure savings contributions on HVAC Heat Pump equipment have not been independently evaluated by IOUs. As directed by the “Disposition for the Smart Communicating Thermostat SCE17HCO54 Rev 1 Workpaper” [Attachment 12], until better verifiable savings are demonstrated, the heat pump equipment is receiving the same treatment (e.g., cooling measure savings) as the central air conditioning equipment.

Since the cooling savings of a heat pump and central air condition unit are similar, the same cooling savings are used. The efficiency of a heat pump varies significantly with outdoor ambient temperature. Therefore, the savings profile of a heat pump will be very different from a natural gas-fired furnace and as a result, the space heating savings cannot be calculated using the same approach. Electric space heating savings are not included for heat pump equipment.

Measure savings potentials for smart thermostat controlling heat pump HVAC equipment (under cooling mode) are conservatively estimated as follow:

1. Baseline characterization for this measure informed by PGE’s Smart Thermostat Program Process Evaluation Report [Attachment 5].
2. Estimate baseline HVAC (compressor + fan + HP supplemental (heating only)) annual energy consumption for SFM, MFM, and DMO using latest MC3 DEER prototype for each Climate Zone using assumptions described in Section 2.
3. Disaggregate baseline fan energy consumption for HVAC cooling per Climate Zone based on CTZ2010 weather cooling (CDD) degree days.
4. Estimate energy savings potentials for cooling for SFM by applying estimated energy savings contributions from PGE Year 1 study. Savings for MFM and DMo are projected per adjustment factors described under Section 2.3.

***HP (Cooling Savings) = [(HP Annual Cooling Energy) + (Fan Energy x (CDD/Total DD))] x (PGE Y1 Savings Estimates %)***

See Attachment 2 for details on approach and results.

# Section 4. Load Shapes

The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

**Building Types and Load Shapes**

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| RES | DEER:HVAC\_EFF\_AC | RES |
| RES | DEER:HVAC\_EFF\_HP | RES |

# Section 5. Costs

## 5.1 Base Case Cost

The base case cost was obtained through online prices research from various retailer websites in the first quarter of 2019. The installed market percent for baseline programmable, non-programmable, and smart thermostats was found using the Evaluation. The percentages of baseline equipment from Section 1.1 were used to weight the online retailer prices to establish a weighted baseline cost.

**Weighted Baseline Material Cost**

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Cost per unit** | **Market Distribution** | **Total Baseline Weighted Cost** |
| Manual Thermostat | $ 28.32 | 12% | $ 40.59 |
| Programmable Thermostat\* | $ 42.21 | 88% |

\*Unknown/Other thermostats were assumed to be programmable thermostats for the estimating market distribution

The total equipment cost includes 8.75% tax. Shipping cost has not been included in the material price as majority of the retailers offer free shipping.

Labor cost was found from RS Means Online database (2018). The bare labor hours (0.40 hours) of an electrician’s time (Residential rates including O&P) was used to estimate the labor cost.

**Base Case: Material, Labor and Full Cost**

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Base Case Material Price** | **Base Case Labor Price** | **Base Case Total Price** |
| Residential Programmable Thermostat | $ 40.59 | $ 26.26 | $ 66.85 |

See Attachment 3 for more details.

## 5.2 Measure Case Cost

Smart Thermostats costs are not contained within WO17 or DEER2019. The measure case cost for the smart thermostats was obtained through online prices research from various retailer websites in the first quarter of 2019. All the smart thermostat models are ENERGYSTAR certified and meet the workpaper eligibility requirements. The total equipment cost includes 8.75% tax. Shipping cost has not been included in the material price as majority of the retailers offer free shipping. Until more updated studies are done, the online retail point of sales pricing is the best available data to support the measure equipment cost.

**Cost Methodology/Approach**

The incremental measure cost is the cost differential of the efficient option over the standard option attributable to features related to energy efficiency performance. A robust analysis would involve developing a taxonomy of features and determining the cost of each feature or component. This is generally done through such methods as product teardowns or hedonic price modeling. However, for thermostats, these methods become unwieldy because it is difficult to develop a standardized set of features due to various possible implementations of the technology and we may not find a reliable correlation between features and price.

The measure cost update is adjusted based on smart thermostat adoption in the Utility programs in 2018. IOU program tracking data suggest that 80% of all smart thermostat rebate applications are for smart thermostat technology with occupancy sensing. The cost per unit is adjusted to include only the standard features of smart thermostats. Evaluation of the measure cost resulted on a total (Program implementation) weighted cost of $183.05.

Attachment 3 (CONFIDENTIAL) details the measure and base cost methodology and analysis.

The labor costs for both the measure and base case are assumed to be the same. Labor costs for both cases is based on RS Means Online database (2018). The bare labor hours (0.40 hours) of an electrician’s time (Residential rates including O&P) was used to estimate the labor cost.

Measure Case: Material, Labor and Full Cost

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** | **Measure Case Material Price** | **Measure Case Labor Price** | **Measure Case Total Price** |
| Residential Smart Thermostat | $ 183.05 | $ 26.26 | $ 209.31 |

See Attachment 3 (CONFIDENTIAL) for more details.

## 5.3 Full and Incremental Measure Cost

The tables below show the calculation of the full and incremental measure costs:

Full and Incremental Measure Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Full and Incremental Costs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| CE-18623 | NR | $ 142.46 | $ 142.46 | N/A |

# Attachments

1. SCE17HC054.1 A1 - Calculation Template 2019\_1 and 2.xlsm
2. SCE17HC054.1 A2 - Summary of Savings.xlsx
3. SCE17HC054.1 A3 - Full measure cost analysis and IMC analysis\_CONFIDENTIAL.xlsx
4. SCE17HC054.1 A4 - MFmDMoScaling\_v05\_09\_2019.xlsx
5. SCE17HC054.1 A5 - PGE Smart Thermostat Program Process Evaluation
6. SCE17HC054.1 A6 - PG&E Smart Thermostat Study - 1st Year Findings .pdf
7. SCE17HC054.1 A7 - PG&E Smart Thermostat Study - 2nd Year Findings .pdf
8. SCE17HC054.1 A8 - PGE SCT\_Cooling Savings\_Approach\_Results\_Memo.docx
9. SCE17HC054.1 A9 - EUL Analysis of SCT Memo-II\_CONFIDENTIAL.pdf
10. SCE17HC054.1 A10 – Res SCT WP Disposition - July 19 2016.docx
11. SCE17HC054.1 A11 – Res SCT WP Disposition - November 8 2016.docx
12. SCE17HC054.1 A12 - Res SCT WP Disposition – April 5 2019.pdf
13. SCE17HC054.1 A13 - MFm HVAC System Cap Analysis
14. SCE17HC054.1 A14 - ST WP Update Plan\_v04\_23\_2019

# References

[469]

[515]

1. Adopted from <https://www.energystar.gov/products/heating_cooling/smart_thermostats> [↑](#footnote-ref-1)
2. Items in Disposition for WPSCGREHC160624A (SCG Smart Thermostat) issued November 8, 2016 That Impact Future Smart Thermostat Workpapers [↑](#footnote-ref-2)
3. CA Energy Efficiency Evaluation Protocols available online: <http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=5212> [↑](#footnote-ref-3)