the cost-benefit of participating; the utilities could do better at helping builders understand how they could truly benefit from the program.

Table 21. Importance of New Homes Programs Technical and Training Components

Program Component	Important (8 - 10 Rating)	Moderately Important (4 – 7 Rating)	Not Important (0 - 3 Rating)	Total Responders
Technical support provided by the utilities	5	8	9	22
Information provided by representatives of the utilities	9	11	2	22
Training seminars provided by the utilities	0	7	15	22
Information provided by the utility websites	12	0	10	22
Company's past participation in a program sponsored by the utilities	13	5	4	22
The program incentive	18	0	4	22

Attribution

The EM&V team is tasked with estimating net savings, which was accomplished by completing NTG research and producing NTG ratios statewide for the new homes programs. In Texas, net savings have been defined as "those savings that are attributable to the programs, inclusive of free-ridership and spillover"[17] based on the definitions of these terms in § 25.181 (c).

The EM&V team used a self-report approach through builder interviews to calculate NTG ratios.

Free-Ridership refers to actions taken by participants (builders) through a program that would have occurred in the absence of the program. In other words, a *free rider* is a program participant who would have made some amount of the program-rebated energy-efficient improvements if the program had not been offered.

Spillover refers to additional energy-efficient equipment installed, or actions taken due to program influences but without any financial or technical assistance from the program. The EM&V team relied on builder interviews to determine the spillover rate.

The final NTG ratio is then calculated using the following formula. The ratio can be applied to the population to determine the final net savings value.

$$NTG\ Ratio = 1 - (Free\text{-}Ridership\ Rate) + (Spillover)$$

As a simplistic example, if a program has a free-ridership rate of 20 percent, and a spillover rate of 8 percent, the NTG ratio would then be:

$$NTG\ Ratio = 1.00 - ((0.20) + (0.08))$$
$$NTG\ Ratio = 0.88, \text{ or } 88\%$$

[17] Evaluation, Measurement, and Verification Plans for Texas Utilities' Energy Efficiency and Load Management Portfolios – Program Years 2012 and 2013 (Final June 12, 2013).

A higher NTG indicates program influence on decisions and high attribution toward behaviors. A lower NTG factor indicates a low level of influence, which may be further indicative of market transformation, a need for incentive restructuring, etc. There are occasions where outliers exist in the data. Outliers are cases that provide responses that extensively deviate from the norm. While important to account for these cases, depending on the project size and the number and composition of survey completes, these data can significantly swing the results.

Within NTG research, the spillover calculation has the potential of capturing large outliers, which could then influence the overall NTG ratio considerably. While it is important to recognize these cases' spillover results, the EM&V team needs to be careful to manage the results such that NTG is not overstated due to potential self-reporting bias. Therefore, the EM&V team will cap the spillover rate calculated for individual market actors at 200 percent.

Summary of Results

Table 22 summarizes the statewide NTG results and the NTG methodology, which are then discussed in more detail below. As already mentioned, the results are based on builder interviews.

Table 22. Net-To-Gross Summary

Program Category	Program Type	Free-Ridership	Spillover	NTG Ratio	NTG Methodology
Residential Market Transformation Program (RMTP)	New Homes	49%	15%	64%	Market actor (builder surveys)

4.3.4.2 Methodology

The EM&V team used builder interviews as the only method to calculate free-ridership and spillover for the new homes programs. No customer surveys were completed for the new homes programs because the utilities do not collect end-use customer information for new homes completed through the programs; this is not surprising given that the programs' upstream implementation focus is working with builders.

Builder free-ridership and spillover results were weighted by the number of total energy-efficient projects completed by each builder and submitted to a utility program to account for a different level of builder activity.

4.3.4.3 New Homes Net-To-Gross Results

Free-Ridership

As mentioned earlier, the NTG approach for the new homes programs differs from other types of programs. While the customer may be aware of the benefits or be involved in the decision, the majority of the program's marketing, outreach, and education are directed to builders. The main intent is to encourage the builders to adopt above-code energy efficiency products and practices that meet each utility's specific requirements. Therefore, it is most important to understand, from the perspective of the builder, what their perception is of their building practice in the absence of the program.

We calculated a free-ridership rate of 48 percent for the new homes programs. The free-ridership rate is based on 28 builder responses.

Spillover

The EM&V team calculated the spillover rate for the new homes programs at 15 percent. The market actor results include responses from 12 unique builders. Several builders provided *don't know* responses to spillover-related questions, in which case we treated them as contributing zero spillover. While this is a conservative approach, it reflects that these builders do not have widespread practices that contribute to spillover like some other builders.

Benchmarking

For residential new construction, the EM&V team reviewed NTG ratios established by four different entities—Nicor Gas and ComEd in Illinois (implemented as one program), Public Service Company of Oklahoma, Oklahoma Gas and Electric, and the collective PAs in Massachusetts. NTG ratios ranged from 65 to 100 percent. The Texas utilities' new homes programs' NTG of 64 percent appears reasonable compared to the benchmarked utilities but also indicates more can be done to increase the NTG ratio and net savings.

4.3.4.4 Considerations for Program Design and Delivery

For the Texas new homes programs, a confluence of factors continues to affect the NTG ratio for these programs, including the fact that many of the builders have been around for a number of years, there are a fair number of production builders, and energy building codes differ across areas. As noted earlier, the majority of home builders interviewed have been building homes through the Texas programs for two to five years, with some (4 of 12) noting they have been participating for 14, 15, even up to 20 years. On the one hand, given the longevity of the Texas new homes programs and their focus on changing building practices, it seems reasonable to assume that it has affected practices in nonparticipating homes and thus has generated spillover. On the other hand, the longevity of the Texas programs virtually assures a substantial number of free riders in the program. In fact, the EM&V team heard during interviews with participating builders that they are generally committed to building energy-efficient homes, whether there is a program incentive or not.

Builder comments from the interviews conducted by the EM&V team reflect the lower NTG ratio:

"Such a hard question. Like I said, everyone feels the same; there's no way you cannot do energy efficiency and still sell a house."

"We didn't know what the incentives were - everyone was happy because we got a rebate on some of this, but we had already decided how we were going to build our homes."

"We have always tried to be a step ahead on energy efficiency; when SEER was 10, we put in 12, we have always done radiant barriers, etc. So we were already doing a lot of these items."

"We don't do this because of the program; we put the stuff in the homes that we do to due right by the customer; it's the right thing to do."

"I'm not really doing anything more than what the competition and market is requiring."

"We've been building homes for so long this way, we just might not strive for the top tier."

Another major factor for new homes programs to contend with is building codes. While Texas has a statewide energy code (IECC 2015), several municipalities have adopted higher codes than what is required at the statewide level. A key challenge surrounding building codes is the enforcement of these codes. Without enforcement, it can often be the case that builders that are not participating in energy efficiency programs are not building to code. Given these challenges, the Texas new homes programs should continue to have their programs evolve as building codes evolve. For example, a couple of the new homes programs have already shifted their focus to a code-based energy savings goal (e.g., new homes must save 15 percent more kWh than a home built to code).

Two critical components to the new homes market that the EM&V team was not able to assess was the nonparticipating builder market and code compliance. A statewide market assessment that includes these two items would strengthen the research and provide further insight into the market and NTG issues.

Raters

The EM&V team spoke with at least one rater representative for each of the four new homes programs in Texas. Rater organizations included in the study vary by the number of home ratings annually (hundreds to thousands), and work with anywhere from three to upwards of "dozens" of builders. All three raters said they anticipate about the same amount of new homes business in 2020, even given the current COVID-19 pandemic. Many of the builders that these raters work with are building to ENERGY STAR standards or similar types of programs (e.g., Environments for Living®).

All three raters we spoke with work with builders across multiple utility new homes programs. The interviews probed these raters on differences in program requirements, marketing, program interactions, etc. by utility. Other than a few variations in program design, raters did not identify differences among the various utilities for this program.

Satisfaction

Raters were asked to rate their level of satisfaction with various elements of the program (very satisfied, satisfied, somewhat satisfied, and not satisfied). As reflected in Table 23, nearly all raters said they were *very satisfied* or *satisfied* with most of the areas discussed. Similar to builder satisfaction ratings, the responsiveness of program staff received the most *very satisfied* ratings, and *the ease of filling out and submitting required program documentation* received the most *not satisfied* ratings.

Table 23. Satisfaction with New Homes Programs Components

Program Component	Number Very Satisfied	Number Satisfied	Number Somewhat Satisfied	Number Not Satisfied	Total Responders
Overall program satisfaction	7	3	0	0	10
Ease of filling out and submitting required program documentation	4	3	0	3	10
Responsiveness of program staff to questions	10	0	0	0	10
On-site inspection process	2	7	1	0	10
Technical support	4	6	0	0	10

Program Requirements and Interactions

Most raters indicated that communication related to program requirements has continued to be pretty clear. When asked about what program requirements builders or subcontractors find hardest to meet, one rater said, "None, as long as the program requirements stay the same." This rater mentioned that, "Sometimes a particular house is not suited well to a duct blaster, so it may not pass, but in general the majority of houses are fine." One rater mentioned that HVAC documentation could be a challenge for subcontractors, particularly smaller ones because they have to have staff to enter the information. Sometimes submitting the AHRI certificate or making sure the subcontractor is completing Manual J forms is a challenge. The third rater mentioned that, due the differences across programs, it could be difficult for builders to understand and adjust their construction to meet program requirements when working across service territories. This rater also mentioned that there are situations where builders make agreements with utilities, but the rater is left out of the communication loop—this can lead to issues in builders meeting their obligations to the utilities.

While raters told us that their builders understand the program requirements, the raters take care of almost all program activities for their builders, helping to ensure program requirements are met. Raters told us they enter all program information into the required portals, from both the builder and rater perspectives. One rater mentioned that they provide their building files to the utility, but then are also required to enter the data on a website. Submitting the information twice can create an environment for human error, which can result in a home being rejected and an unhappy builder. As a result, this rater mentioned that streamlining the program requirements so they can stay on top of their paperwork would be very helpful. All three raters mentioned that they are receiving the support they need within a timely manner, which is also reflected in the number of raters rating *responsiveness of program staff* as *very satisfied*.

Similarly, raters we spoke with told us that the process for certifying to the IECC 2015 specifications is going fine. This energy code has been in place for a few years now, so other than a few potential outliers, raters told us that almost all builders work in jurisdictions that have adopted IECC 2015. Additionally, raters said that subcontractors know what the IECC 2015 requirements are and that the only additional training needed would be training done in Spanish.

Future Challenges and Recommendations

When asked what they think the biggest challenges are for constructing or selling energy-efficient homes going forward, two of the three raters noted code changes, and the third rater said overcoming the perception that all new homes are energy efficient. Raters suggested that education is needed to change this perception and increase demand for energy-efficient homes.

"Just depends on where the code goes; foresee insulation of envelope of home will have to change."

"Code changes. The builders will just have to deal with it, and decide whether to go with above code programs."

"Perception that all new homes built these days are energy efficient; consumers take this for granted, and it's not true. Energy efficiency varies by builder. My company offers an energy guarantee."

When asked for suggestions about how the new homes programs participation process could be streamlined, one rater said that all three programs they work with are now allowing batch uploads. Because they work mainly with production builders, the batch upload process has been "really helpful." One rater said the input system is "clunky," and not working correctly. The third rater said their builders would like to have the ability to use "Docu-sign" documents; they don't want to have to print things out.

The most critical support the new homes programs could provide to raters in the near future is providing close communications related to programs and program changes.

"Help the raters communicate with their builders about how the programs are changing and have conversations about which path to compliance/best path to compliance for each builder. There have been times where program management staff tells the builders to do one thing, but the raters were telling the builders something else. Need to all work together more cohesively."

"Just continue to provide information and updates as to what matters for claiming savings, and make database updates."

4.4 UPSTREAM MARKET TRANSFORMATION PROGRAMS

Upstream market transformation programs were a *high* evaluation priority in PY2019 as they were relatively new in the Texas portfolio, but have been increasing as a percentage of statewide savings. EM&V activities included conducting desk reviews, gathering process information, and researching NTG ratios for these measures through retailer interviews triangulated with secondary research.

4.4.1 Program Overviews

Advanced Lighting MTP: The Advanced Lighting MTP offers point-of-purchase discounts to residential customers at participating retail stores for the purchase of qualified (i.e., ENERGY STAR-rated) high efficiency LED lighting products.

Retail Platform MTP: The Retail Platform MTP provides incentives to residential and small commercial customers through in-store discounts for qualifying ENERGY STAR-rated LED lighting and energy-efficient appliances.

Home Lighting MTP: The Home Lighting MTP offers customers in-store discounts for the purchase of LEDs through qualifying retailers.

Texas Appliance Recycling: The Texas Appliance Recycling program is designed to encourage customers to recycle old refrigerators and freezers.

Residential Recycling MTP: The Residential Recycling MTP offers customers no-charge pick-up services for old refrigerators and freezers and offers incentives for each unit picked up.

4.4.2 Key Findings and Recommendations

Key findings and recommendations are presented below based on the NTG research, tracking system review, and desk reviews conducted by the EM&V team.

Key Finding #1: The LED market is transforming but is not yet transformed.

Interviews with participating upstream retailer stores, manufacturer sales data, and benchmarking from similar utility programs indicate some level of market transformation of LEDs as well as a continued role for the programs in the near term.

Recommendation #1a: Use an NTG of 50 percent to assess net savings of upstream lighting programs to ensure they are still a cost-effective mechanism to deliver savings to ratepayers.

Key Finding #2: Lamp quantities and savings are not clearly tracked in the data.

Previous guidance from the EM&V team for upstream lighting programs recommended five percent of upstream lighting program benefits and costs be allocated to commercial customers, with the remaining 95 percent allocated to residential customers. It is not clear from the tracking data if utilities are implementing this correctly. In some cases, the total quantity is tracked alongside the commercial quantity, but in others, only a single input for quantity is tracked. The EM&V team also found that in some cases, there were no indicators as to whether savings were calculated using the residential or commercial methodology.

Recommendation #2a: Utilities should consider tracking total lamp quantity, residential quantity allocation, and commercial quantity allocation along with corresponding savings in separate columns to verify the residential and commercial allocation is applied accurately.

Key Finding #3: Documentation does not clearly match the tracked data.

In some cases, the EM&V team found that invoices provided did not line up with the tracking data.

Recommendation #3a: Invoices should clearly show the total quantity of each incented lamp sold per store. The utilities should consider linking stores and invoices with a tracking data ID in the database for quality control purposes.

Key Finding #4: Some of the incented lamps were not ENERGY STAR-certified.

While it is acceptable to incent lamps that are not ENERGY STAR-certified, lamps still need to be third-party tested and qualify under the ENERGY STAR requirements. To ensure only high-quality equipment is incented, the TRM calls for products to be ENERGY STAR-qualified as outlined in the latest ENERGY STAR specification. In some cases, the EM&V team found that the incented lamps were not ENERGY STAR-qualified.

Recommendation #4a: For ease of implementation, utilities should consider requiring ENERGY STAR certification for incentivized upstream lamps. In lieu of ENERGY STAR certification, utilities should collect test results or other third-party certifications.

Key Finding #5: A utility allocated five percent of upstream lighting savings to the residential sector, rather than five percent of quantity.

This utility under-claimed savings for the commercial sector by allocating savings, rather than quantity. The commercial sector can claim higher annual savings per bulb since it assumes that bulbs in a commercial setting are used for more hours.

Recommendation #5a: Review the methodology to allocate savings to the commercial sector from upstream lighting programs and verify that savings are claimed based on quantity.

Key Finding #6: The appliance recycling programs appear to be tracking and calculating savings accurately.

The EM&V team found that the appliance recycling programs are collecting and tracking data and documentation properly, leading to realization rates of 100 percent for both energy and demand savings for each program.

Recommendation #6a: Utilities should continue QA/QC practices as those appear to be working.

4.4.3 Impact Analysis

As part of the impact evaluation, the EM&V team conducted desk reviews for a sample of projects from the upstream lighting and recycling MTPs. The EM&V team applied the method prescribed in the PY2019 TRM 6.0 to verify energy savings and demand reduction for each measure sampled.

The EM&V team conducted a tracking system review on the upstream lighting MTPs. Savings adjustments were not recommended for these programs due to the new nature of the programs. The process recommendations are a result of findings during the impact analysis.

The EM&V team conducted desk reviews on the appliance recycling MTPs. Random samples of five desk reviews were drawn from each utility with appliance recycling programs. The realization rate for these programs was 100 percent for both energy and demand savings.

4.4.4 Process and Net-to-Gross Results

Next, we present detailed process findings from participating upstream retailer interviews.

4.4.4.1 Respondent Firmographics

All 13 interviewees held either a managerial or supervisory role within their company and had experience with or a responsibility for lighting stocking and sales. Experience with lighting stocking and sales varied among those interviewed, with two interviewees reporting having less than six months of experience, six reporting one to ten years of experience, and four reporting more than ten years of experience. Twelve respondents were responsible for the lighting stocking and sales for one location. The remaining respondent was responsible for 47 stores in total, all of which have participated in the 2019 upstream lighting program.

4.4.4.2 LED Stocking and Sales Trends

Retailer interviewees report that most of the shelf space for lighting is devoted to LEDs. Four retailers reported that 80 percent or more of their shelf space is devoted LEDs, three additional retailers said LEDs take up about 70 percent or more of their lighting shelf space, and the remaining retailers could not provide a breakdown. One retailer who could not provide a breakdown because it changes depending on the products coming in and out; but did indicate most of the shelf space was dedicated towards LEDs, but that also varies by bulb type. When asked if the amount of shelf space devoted to the different bulb types has changed over the past year, six of eight respondents said that it has, citing reasons such as the marketing moving towards LEDs.

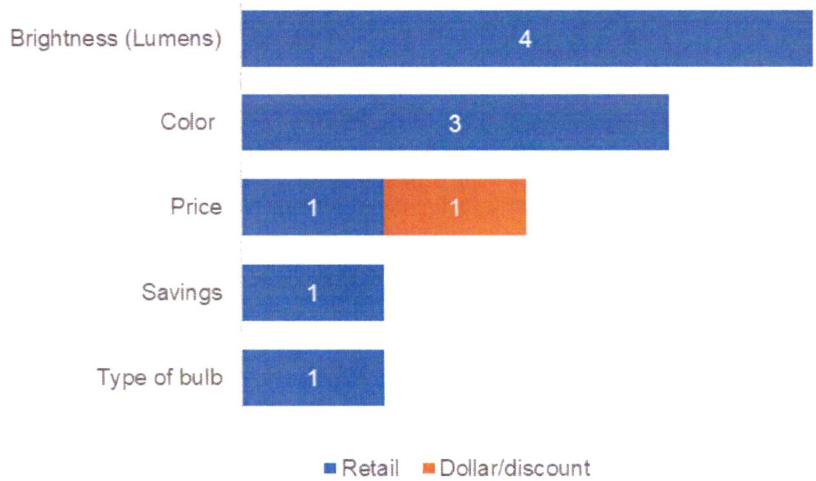
Most retailers (9 of 13 respondents) sold LED bulbs that were not discounted by the Texas upstream lighting programs, and some respondents also sell LEDs that are not ENERGY STAR-rated (6 of 12 respondents). As far as the sales of the bulbs, three respondents sold more ENERGY STAR-rated bulbs, two respondents sold more non-ENERGY STAR-rated bulbs, and one respondent indicated their sales of ENERGY STAR-rated and non-ENERGY STAR-rated bulbs were about the same.

Most respondents estimated that their sales of LEDs in 2019 were not discounted by the program, which ranged from 50 percent to 90 percent. Two respondents estimated sales of LEDs discounted by the program were 10 to 20 percent, and another two respondents were between 30 and 40 percent. Two respondents felt their sales were split in half between discounted and non-discounted. Five respondents had a hard time estimating the percentage of LEDs that were discounted by the program.

All eight retailers mentioned selling a wide variety of LED bulbs in 2019, including general use, spotlight, decorative, night lights, and holiday lights. Two respondents also mentioned selling fluorescent replacements, and one additional respondent also mentioned selling tubular LEDs.

Retailers identified the biggest factors customers typically look for in shopping for lighting products as the lumens or bulb brightness (4 respondents) and the color of the bulb (3 respondents). Other factors include the *price* (2 respondents), the type of lighting product needed (1 respondent), and the savings (1 respondent). Figure 27 shows factors determining customer lighting purchases as reported by different retailers.

Figure 27. Factors Determining Customer Lighting Purchases as Reported by Retailers



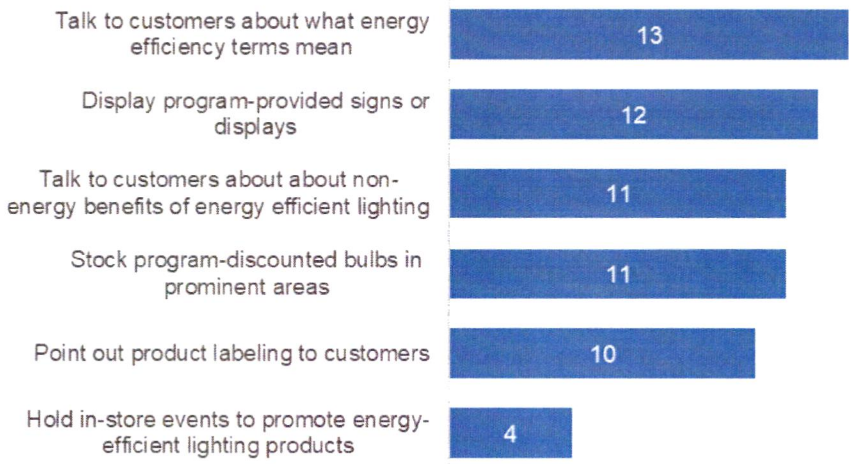
*Note: Multiple responses allowed.

4.4.4.3 Program Marketing

All but three retailers (10 of 13 respondents) mentioned receiving assistance from Texas upstream lighting programs to help sell energy-efficiency lighting by displaying program-provided signs and displays. One respondent indicated the program also aids through in-store promotional events as well as customer education via the in-store signage.

Most retailers reported taking several actions to promote and advertise program-eligible products in their stores. All 13 retailers said that they talk with customers about what energy efficiency terms such as *ENERGY STAR*, *lumens*, or *watt equivalence* mean, and all but one retailer displayed program-provided signs or displays. Most retailers also talk with customers about non-energy benefits of energy-efficient lighting such as reliability, light quality, or dimming ability, and stocking program-discounted bulbs in prominent areas such as endcaps, wings, or stack-outs (11 respondents each).

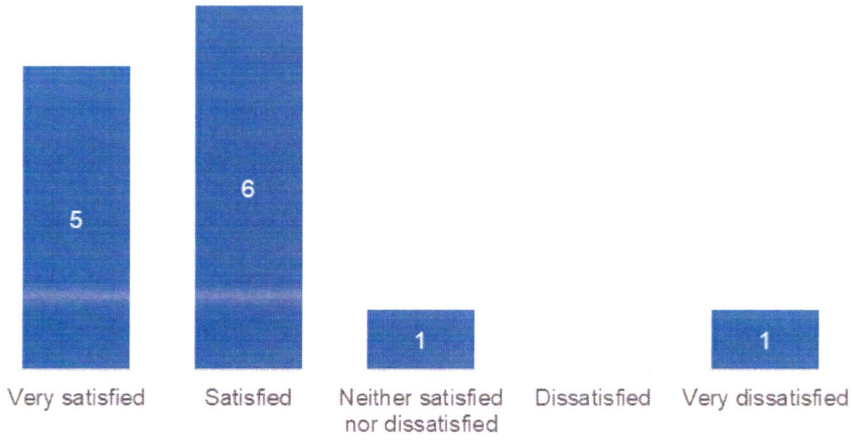
Figure 28. Activities Retailers do as Part of Program Participation (n=13)



4.4.4.4 Participant Experience and Satisfaction

Retailers reported high satisfaction with the program overall. Interviewees were asked to rate their satisfaction using the following scale: very satisfied, satisfied, neither satisfied nor dissatisfied, dissatisfied, or very dissatisfied. Eleven of the 13 retailers interviewed said they were *very satisfied* or *satisfied* with the program. Interviewees most commonly mentioned that customers received a discount (5 respondents), that the program helped increase sales (3 respondents), and that program staff was helpful (2 respondents). Other reasons mentioned included the availability of signage and that customers are drawn to the bulbs (1 respondent each).

Figure 29. Retailer Satisfaction with the Program (n=13)



The one respondent, who indicated they were *very dissatisfied* with the program overall, indicated they did not have any information or education about the program, and that the only reason the respondent knew about Oncor is because of, "the little stickers," and the respondent thought they were, "not very explanatory." The one interviewee who said they were *neither* *satisfied nor dissatisfied* with the program noted that they were not familiar with anyone coming in to discuss the program.

Four of the 13 respondents mentioned no changes were needed to the program. Of the remaining nine respondents who had a recommendation, the most common recommendation by retailers was the need for more or better signage or promotional materials (4 respondents). Three respondents mentioned more support from the project team by coming to the store to talk with the staff. Other responses included the need for training or better packaging due to products being broken upon arrival (1 respondent each).

Most retailers who indicated there were barriers to selling LEDs, identified the greatest barrier as understanding the technology (4 of 7 respondents). The aesthetic, price, and availability were also factors that prevented retailers from selling LEDs (1 respondent each).

Net-to-Gross Results

To support the LED NTG analysis, the EM&V team used a triangulated approach using telephone interviews with participating upstream retailer stores, a review of proprietary manufacturer sales data and benchmarking from similar utility programs.

For each of the evaluation activities, free-ridership rates were estimated, and NTG ratios were calculated using the following equation:

$$\textit{NTG Ratio} = 1 - \textit{Free-Ridership}$$

Based on the collective results of the evaluation activities, the EM&V team recommends an NTG ratio of 50 percent. Table 24 shows the free-ridership and NTG result estimates by analysis activity. The retailer interviews, when weighted by the number of bulbs sold, yielded the highest free-ridership (70 percent), while the retailer interview not weighted by bulbs sold also yielded the lowest free-ridership (42 percent). It is important to consider both given the limited sample size. The EM&V team also believes manufacturer sales data is an accurate gauge of market transformation and NTG. The EM&V team reviewed proprietary sales data from manufacturers and found the retailer 50 percent NTG recommendation is supported by recent data of halogen and LED sales. Interesting, further supporting this recommendation is very recent data of sales during the pandemic suggesting an uptick in halogen sales.

Table 24. LED Free-Ridership and Net-to-Gross Result Estimates

Method	Free-ridership estimate	Net-to-gross estimate
Retailer NTG* weighted	70%	30%
Retailer NTG* unweighted	42%	58%
Manufacturer data	40 to 50%	50% to 60%
Utility program benchmarking	33% to 81%	19% to 67%
Final recommendation	**50%**	**50%**

*NTG results are weighted by program savings at the retailer level and ranged between 8 percent and 100 percent between CenterPoint, Oncor, and Xcel Energy. Overall unweighted NTG results were 58 percent.

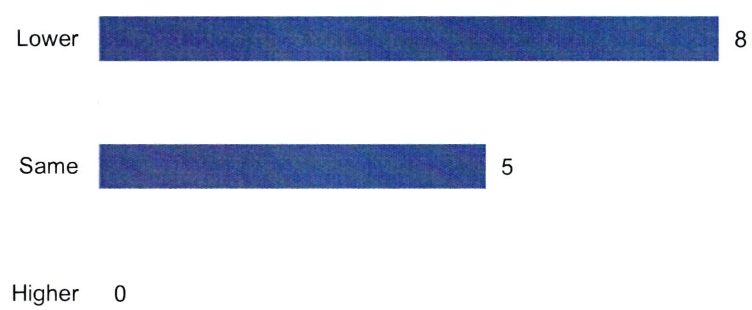
The following sections detail the NTG result estimates by evaluation activity.

4.4.4.5 Retailer Interviews

To assess free-ridership for participating retailers, thirteen retailers were asked to estimate what the change in their 2019 sales of program-qualifying equipment would have been if the program discounts had not been available. The survey asked, "If the price discounts and other assistance from the program had not been available, do you think your sales of these LED bulbs would have been the same, lower, or higher in 2019?" If the response was *the same* or *higher*, then the program did not influence sales, and free-ridership is 100 percent.

Eight of the 13 participating retailers reported program influence on LED sales in 2019 (see Figure 30below). After weighing the results using the retailer's annual savings, free-ridership was estimated to be 70 percent for an NTG ratio of 30 percent.

Figure 30. 2019 Sales Effect in the Absence of the Program (n=13)



Retailers that said LED sales would have been the same indicated this was because LEDs are now the primary option available for lighting purchases and because people already come in knowing what type of bulb they want. Comments from the retailers:

> *"I can point out that the sticker says these bulbs are at this price due to [utility]. I don't have one customer I can remember asking me, 'where are those light bulbs that are discounted by [utility]?' The general consumer that comes in here looking for bulbs, one way or another, they don't care about the [utility] discount. I mean, you can point it out to them, but they just want cheapness and a certain color. If they see an LED light bulb that costs $15 and one that costs $5, they're going to take the $5 one. GE makes three different bulbs: basic, classic, and HD. The people will often buy the basic because it's the cheapest."*

> *"I'm not saying they're not looking at the price; they want a certain type of bulb the one they have in their house. They don't care about the price; they want to get the same thing that they already have."*

> *"Because everything is going to LED. What really makes me think it would be the same is because you come in now, and the only selection that you have is LED. If 90 percent of our selection is LED, they're going to pick up LED, and almost all of our LEDs are ENERGY STAR-rated."*

4.4.4.6 Review of Manufacturer Sales Data

The EM&V team reviewed proprietary sales data from manufacturers and found halogen and LED sales data supports the 50 percent NTG recommendation. During the pandemic, manufacturers are also showing an additional uptick in halogen sales and suggest there may be longer-term effects from the pandemic.

4.4.4.7 Net-to-Gross Benchmarking

Benchmarking of other utility LED upstream lighting programs was conducted. The EM&V team looked at NTG results from nine utility programs with research from either PY2018 or PY2019. NTG results ranged between 19 percent and 67 percent. The benchmarking research supports the reasonableness of the EM&V team's NTG recommendation of 50 percent.

Table 25. LED Upstream Lighting Program Net-to-Gross Benchmark

Utility	State	Year	NTG Ratio	Program Type	Net-to-Gross Summary
Entergy Arkansas, LLC	AR	2019	53%	Lighting and appliances retailer programs	Price elasticity model found 77 percent free-ridership, retailer surveys yielded 47 percent free-ridership.
Southwest Electric Power Company (SWEPCO) Arkansas	AR	2018	67%	Lighting and appliances retailer programs	Price elasticity model found 33 percent free-ridership, recommended NTG ratio higher as spillover included.
Massachusetts Program Administrators	MA	2019	35%	PAs, EEAC consultants, and evaluators to review and discuss retrospective and prospective NTG estimates	Prospective results recommended an NTG of 30 percent in 2020 and 25 percent in 2021.
PECO Energy Company	PA	2019	51%	Lighting, appliances, and HVAC programs (standard LEDs)	Free-ridership for standard LEDs is 53 percent with a spillover ratio of 4 percent.
PECO Energy Company	PA	2019	46%	Lighting, appliances, and HVAC programs (specialty LEDs)	Free-ridership for specialty LEDs is 58 percent with a spillover ratio of 4 percent.
Duquesne Light Company	PA	2018	43%	Energy efficient products programs (standard and specialty LEDs)	Also had a free kit component (8 bulbs), estimated an installation rate of 75 percent.
FirstEnergy Met-Ed	PA	2019	32%	Energy efficient products programs (retailer survey)	Including results from a general population survey, NTG is 29 percent.

5.0 CROSS-SECTOR PROGRAMS

This section presents results found in the evaluation of the commercial and residential programs that apply to measures that are offered to both sectors as follows: multifamily and HVAC tune-ups.

HVAC tune-ups continued as *medium* evaluation priorities in PY2019 as savings recommendations from the PY2017 EM&V were to be fully implemented in PY2019. However, some additional changes were still identified in PY2019 as the mix of tune-ups has become increasingly residential and commercial instead of primarily residential.

This section summarizes the key findings and recommendations from the PY2019 evaluation of AC and HP tune-ups. The recommendations in this report are to be considered by the utilities for PY2021 implementation and will also be incorporated into the PY2021 Texas TRM 8.0.

5.1.1 Background

One of the key recommendations from the PY2016 Statewide Portfolio Report was that calibration of the model used to develop the stipulated efficiency losses[18] should be conducted annually by including the most recent year's M&V data. Additionally, the report also recommended using a three-year rolling average to include changes in the efficiency loss over time while also preventing drastic changes in program savings that can result from using a single year's values. The PY2016 efficiency loss values for the residential population were unexpectedly low, and recommendations were made to monitor the efficiency loss values on an annual basis to determine if (1) PY2016 reflected a decreasing trend over time or (2) if it was an outlier. Monitoring the efficiency loss values remained important because PY2016 data was still used within PY2019 calculations using a rolling average of the previous three years of program data. Since PY2016, efficiency loss values have been on an upward trend for all sectors and refrigerant charge adjustment status.

In PY2019, over 10,000 tune-ups were provided to residential and commercial customers through four Texas utilities across five different programs, as shown below in Table 26.

[18] Efficiency loss is the ratio of the air conditioner's measured efficiency before and after a tune-up.

Table 26. PY2019 Tune-Up Summary by Utility and Program

Utility	Market Transformation Program	Energy Savings		Tune-Up Count
		Reported kW	Reported kWh	
AEP Texas – Central Division	CoolSaver	3,845	9,162,373	4,057
CenterPoint	Retail Electric Provider CoolSaver	3,962	10,064,848	6,193
El Paso Electric	Residential Solutions	12	21,848	15
	Small Commercial Solutions	1	1,486	2
Entergy Texas	CoolSaver	38	95,744	63
Total		**7,859**	**19,346,299**	**10,330**

5.1.2 Key Findings and Recommendations

Key findings and applicable recommendations are presented below based on the information gathered in reviews across multiple utilities as well as discussions with the implementation contractor.

Key Finding #1: Test-in energy efficiency ratio (EER), on average, is lower than in previous years.

Recommendation #1a: Continually monitor all trade allies' test-in data to identify low EER trends from specific contractors.

Key Finding #2: M&V data from both Texas and New Mexico was used to develop the efficiency loss values used in reported savings calculations.

During the review of the PY2019 M&V plan, the EM&V team found that the efficiency loss factors used for the state of Texas were developed using M&V data from both Texas and New Mexico. The EM&V team requested that all efficiency loss factors be developed using only data from the state of Texas to avoid any influence from other outside regions and weather zones. The EM&V team re-calculated the efficiency loss values using only the 2016—2018 Texas M&V data, which was then used in the evaluated savings calculations. The Texas-only efficiency loss values were nearly identical to the Texas and New Mexico values presented in the M&V plan due to the small sample size of the New Mexico M&V data, which resulted in a minimal evaluated savings adjustment. The EM&V team recommends using only M&V data from the state of Texas to determine efficiency loss values in future evaluations.

Recommendation #2a: Utilize only M&V data from Texas to determine efficiency loss values.

Key Finding #3: Greater than 10 percent of tune-ups received both test-in and test-out M&V field measurements across all stratifications.

In PY2019, approximately 17 percent of tune-up measures in Texas collected both test-in and test-out M&V field measurements by the programs—referred to as *full M&V*—which is a slight decrease in percentage from the last evaluation in PY2017, but still well beyond the ten percent M&V goal. Despite the slight overall decrease in M&V percentage, the total commercial project percentage increased from 6 percent in PY2017 to 11 percent in PY2019. Both residential and commercial sectors achieved beyond their 10 percent goal, which imparts confidence in the calculated efficiency loss values for both sectors. The EM&V team recommends continuing to monitor M&V data collection quantities across sectors to maintain the ten percent M&V sample across both commercial and residential.

Table 27. Measurement and Verification Tune-Up Counts by Sector

Utility	Sector	Tune-Up Count	Measurement and Verification Count	Measurement and Verification Percentage
AEP Texas – Central Division	Commercial	2,144	249	12%
	Residential	1,913	320	17%
CenterPoint	Commercial	407	23	6%
	Residential	5,786	1,153	20%
El Paso Electric	Commercial	2	2	100%
	Residential	15	3	20%
Entergy Texas	Residential	63	7	11%
Total	**Commercial**	**2,553**	**274**	**11%**
	Residential	**7,777**	**1,782**	**23%**

Recommendation #3a: Tune-up measures should continue to collect a robust M&V sample for both commercial and residential projects.

5.1.3 Reported Tune-Up Savings Methodology

As part of the PY2016 evaluation, the M&V team recommended using a three-year rolling average of efficiency loss data obtained from tune-ups statewide in Texas by sector (residential and commercial), and by whether a refrigerant charge adjustment was applied. In PY2019, the implementer used data from both Texas and New Mexico tune-ups to develop the efficiency loss factors. After a discussion with the Texas PUC, tune-up data exclusively from Texas was required to be used for the evaluation. The reported PY2019 efficiency loss analysis is presented in Table 28. The reported efficiency loss factors include M&V data from both Texas and New Mexico, and the evaluated efficiency loss factors include M&V data from only Texas. When compared to the reported efficiency loss values, the residential sector—without a refrigerant charge adjustment—was the only sector whose efficiency loss value changed when analyzing data from only Texas. In discussion with the implementer, this was due to a small sample size from New Mexico, which did not impact the evaluated efficiency loss vales much when removed from consideration.

Table 28. Reported Efficiency Loss Values (PY2016–2018 Averages)

Sector	Refrigerant Charge Adjusted	Reported Efficiency Loss Factor	Evaluated Efficiency Loss Factor
Commercial	No	0.143	0.143
	Yes	0.204	0.204
Residential	No	0.110	0.109
	Yes	0.175	0.175

Approximately 10 percent of tune-ups are anticipated by the CoolSaver program to receive full M&V in a given year for use in the annual efficiency loss updates. Table 29 shows the total tune-ups and M&V quantities by utility that were completed in PY2019. All four utilities were above 10 percent on their tune-up projects, which helped bring the statewide average to 17 percent.

Table 29. PY2019 Measurement and Verification Summary by Utility

Utility	Tune-Up Count	Measurement and Verification Count	Measurement and Verification Percentage
AEP Texas – Central Division	4,057	569	14%
CenterPoint	6,193	1,176	19%
El Paso Electric	17	5	29%
Entergy Texas	63	7	11%
Total	**10,330**	**1,757**	**17%**

5.1.4 Evaluation, Measurement, and Verification Approach

As a first step, the EM&V team conducted a complete tracking system review for all four utilities that reported tune-ups in 2019. The review was then followed by an in-depth review of the M&V sample collected in the field by the programs and an analysis of the current program year's efficiency losses. The implementer provided a combined M&V dataset for tune-ups in Texas from 2016 through 2018. The efficiency loss factors calculated by the EM&V team were the key savings assumption for this measure.

As part of the EM&V team's evaluation, a comprehensive review of the full M&V sample from 2016 through 2018 was completed. The tracking datasets from 2016 through 2018 were combined into a single dataset for analysis. The combined M&V dataset included 5,229 individual tune-ups collected by the programs over the previous three program years. Each tune-up measure was tested to assure data validity before analysis of the efficiency loss values. Before the analysis of the full M&V sample, the EER_{pre} and EER_{post} values were validated as appropriate when they were greater than zero for both values. Seven tune-ups were found invalid per the EER check and were excluded from further analysis.

A total of 5,222 tune-up measures passed data checks and were considered valid. Next, the dataset was separated for tune-ups with an refrigerant charge adjustment (RCA) and without an RCA. This resulted in identifying 1,929 tune-ups without an RCA and 3,293 tune-ups with an RCA.

Both datasets were reviewed for outliers. Outliers can occur for various reasons, but one of the most common reasons is due to a unit that is not tested at full-load conditions in either the pre- or post-tune-up case. The outlier review was accomplished by calculating and comparing the pre- and post-tune-up compressor powers using the data fields for *CompressorVolts* and *CompressorCurrent*. Since all testing is supposed to occur at or near full-load conditions, a difference in the compressor power between pre- and post-tune-up measurements indicates one of the two measurements may not have been conducted at full load conditions. The differences between the compressor power values were then divided by the nominal tonnage of the units to normalize the differences by capacity. Finally, the statistical ranges of the resulting values were analyzed, and any value that was more than three standard deviations from the mean was excluded from the efficiency loss calculations. A total of 137 tune-ups were identified as outliers from the compressor power test and excluded from the analysis.

5.1.5 Results

The number of M&V tune-ups validated by year, including all M&V data, is presented in Table 30. PY2016 and PY2017 were the two years with the lowest exclusion rates since 2011 when data was available. PY2018 however, saw a substantial uplift in the number of exclusions and represents the highest exclusion rate since data collection began in PY2011. This uplift was primarily driven by one trade ally who completed 114 of the 126 projects and noted by the EM&V team.

Table 30. All Measurement and Verification Tune-Ups Validated by Year

Year	Total Measurement and Verification Projects	Passed Data Checks	Total Projects Excluded	Exclusion Rate
2016	1,265	1,255	10	0.8%
2017	1,614	1,606	8	0.5%
2018	2,350	2,224	126	5.7%
Total	**5,229**	**5,085**	**144**	**2.8%**

Table 31 below shows the average test-in and test-out EERs by program year along with the standard deviation. Average test-out EERs remained similar across all three program years. Test-in EERs for PY2018, however, saw a drastic decrease compared to PY2016 and PY2017. The PY2018 average test-in EER was 15.9 percent lower than the weighted average between PY2016 and PY2017. This decrease in average test-in EER was present across all participating utilities.

Table 31. Average Test-In and Test-Out Energy Efficiency Ratio by Year

Year	Total M&V Projects	Average Test-In EER (AHRI Corrected)	Test-In Standard Deviation	Average Test-Out EER (AHRI Corrected)	Test-Out Standard Deviation
2016	1,265	9.86	3.14	10.77	2.39
2017	1,614	9.42	2.80	10.71	2.25
2018	2,350	8.08	2.59	10.62	2.24
Total	**5,229**	**8.92**	**2.90**	**10.68**	**2.28**

Table 32 shows the PY2018 average test-in and test-out EERs by trade ally along with the standard deviation. The trade ally names have been removed to remain anonymous. The EM&V team identified trade ally #1 as being an outlier, which is the previously mentioned trade ally that completed 114 of the 126 projects that were initially excluded from the sample. They completed a large number of projects with a low average test-in EER.

Table 32. PY2018 Average Test-In and Test-Out Energy Efficiency Ratio by Trade Ally

Trade Ally	Total Measurement and Verification Projects	Average Test-In EER (AHRI Corrected)	Test-In Standard Deviation	Average Test-In EER (AHRI Corrected)	Test-Out Standard Deviation
1	369	6.53	2.00	10.19	1.82
2	31	9.08	1.43	10.50	1.38
3	259	7.95	2.84	10.62	2.85
4	265	8.74	1.75	10.52	1.49
5	5	9.79	2.37	12.71	1.67
6	25	6.86	2.51	10.82	1.74
7	47	7.36	2.51	9.40	1.54
8	8	4.90	3.05	9.26	2.76
9	3	10.86	1.08	12.13	1.53
10	5	10.42	2.71	13.08	1.33
11	1	12.18	N/A	12.50	N/A
12	1	7.44	N/A	8.19	N/A
13	35	8.93	1.74	11.00	1.67
14	188	9.68	2.16	11.65	2.38
15	3	11.93	2.90	12.22	1.95
16	268	6.46	2.32	10.29	1.98
17	69	8.42	2.26	10.29	2.05
18	54	9.20	2.42	11.20	2.53
19	7	7.61	2.60	10.02	1.65
20	2	9.30	0.91	10.17	0.09
21	2	9.39	1.33	14.17	2.57
22	1	9.05	N/A	9.68	N/A
23	4	8.69	4.26	11.92	3.11
24	316	8.71	2.22	10.78	2.11
25	56	8.14	1.82	10.38	1.60
26	23	5.98	2.82	9.17	2.22
27	7	10.43	2.76	11.91	2.29
28	4	10.81	4.49	11.58	4.66
29	5	7.74	0.88	10.51	2.19
30	2	8.49	1.29	9.27	2.29
31	1	8.87	N/A	10.20	N/A
32	72	9.47	2.33	11.41	2.33

Trade Ally	Total Measurement and Verification Projects	Average Test-In EER (AHRI Corrected)	Test-In Standard Deviation	Average Test-In EER (AHRI Corrected)	Test-Out Standard Deviation
33	212	8.92	3.13	10.73	3.01
Total	**2,350**	**8.08**	**2.59**	**10.62**	**2.24**

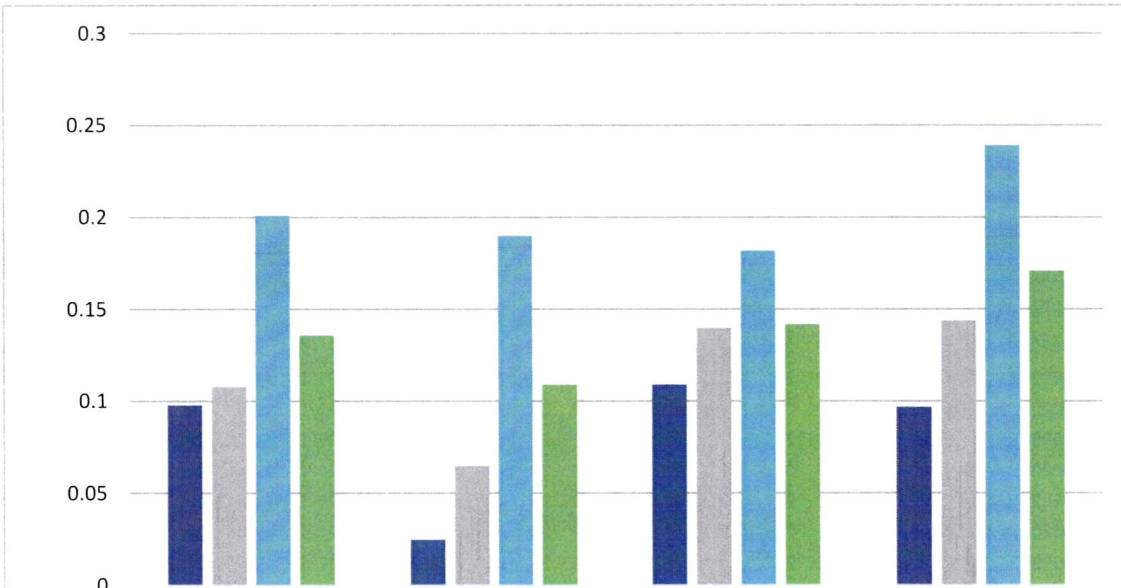
Because trade ally #1 was found to have an average test-in EER lower than the population average with a relatively small standard deviation, removing this trade ally reduced the total M&V projects in PY2018 to 1,981. The impact of removing this trade ally can be seen in Table 33. Removing this one trade ally impacted the mean and standard deviation of the entire PY2016 thru PY2018 sample, which impacted exclusions from all years.

Table 33. Final Measurement and Verification Tune-Ups Validated by Year

Year	Total M&V Projects	Passed Data Checks	Total Projects Excluded	Exclusion Rate
2016	1,265	1,249	16	1.3%
2017	1,614	1,598	16	1.0%
2018	1,981	1,945	36	1.9%
Total	**4,860**	**4,792**	**68**	**1.4%**

The 4,860 Texas tune-ups that passed the data checks were then analyzed by year, by sector (i.e., residential, commercial), and status. The results are shown in Figure 31. In all sectors and RCA status, the average loss value increased every year, with the largest increase observed in PY2018. This increase is attributed primarily to the lower average test-in results than observed in previous years.

Figure 31. Texas Average Efficiency Losses by Sector, Year, and Refrigerant Charge Adjustment



	No RCA Commercial	No RCA Residential	RCA Commercial	RCA Residential
2016	0.098	0.025	0.109	0.097
2017	0.108	0.065	0.14	0.144
2018	0.201	0.190	0.182	0.239
All	0.136	0.109	0.142	0.171

5.2 MULTIFAMILY

5.2.1 Program Overviews

Multifamily buildings receive incentives from both residential and commercial incentive programs using the residential and HTR SOP and MTP delivery. Multifamily buildings receive incentives for a wide range of measures similar to single-family homes. If the buildings are master metered, the energy savings and incentives are provided by the commercial programs, while units that are individually metered are included in the residential programs. The measures provided to any multifamily units are identical and include, but are not limited to, lighting, water-saving, envelope, and HVAC measures.

The evaluation of multifamily buildings this year was completed through the residential consumption analysis methodology described in Section 4 and through the commercial programs method described in Section 3.

5.2.2 Key Findings and Recommendations

Key Finding #1: The TRM does not differentiate savings for multifamily from single-family or manufactured homes.

The EM&V team conducted a consumption analysis comparing the performance of implemented measures versus the TRM deemed savings values. The detailed results in the *residential key findings and recommendations* section apply to the multifamily buildings in both the residential and commercial sectors.

The EM&V team isolated the results of the multifamily buildings compared to the single-family units. Several discrepancies were identified that impacted multifamily residences greater than single-family residences. *Air infiltration* and *duct sealing* were identified in the consumption analysis as larger discrepancies because the TRM deemed savings methodology does not take energy-saving advantages into account. Advantages may include shared walls, equipment within conditioned space, and fewer exterior walls than in single-family units).

The master-metered multifamily building desk reviews supported this finding by the commercial evaluation. The multifamily air infiltration improvements were measured at each apartment where there was infiltration both from the outside and adjacent units. Side-by-side apartment improvements would count both the infiltration from outside and infiltration between units, thereby overstating the reduction once added together.

Furthermore, a unique situation was identified when installing individual unit HPs (decentralized systems) to replace a centralized heating and cooling system. This type of project switches systems and requires that the baseline be adjusted to match the decentralized system. The TRM does not provide specific guidance for handling this in a multifamily building. The projects evaluated assumed an electric resistance decentralized heating system is the baseline. This assumption increases the electric consumption baseline over that of the actual baseline consumption and causes a disconnect between the results of the consumption analysis and the claimed savings. Improved guidance in the TRM will define the adjustment more clearly and provide the level of adjustment expected in future consumption analysis comparisons.

Recommendation #1a: The EM&V team recommends all residential retrofit measures are updated to increase the accuracy of the deemed savings. The TRM working group will update the PY2021 TRM to include guidance for claiming multifamily savings as well as updated testing guidance.

6.0 LOAD MANAGEMENT PROGRAMS

Load management programs were designated *medium* evaluation priorities in PY2019 due to their significant contribution to capacity (kW) savings and the new nature of the residential demand response programs, as well as recent changes in TRM methodologies for the commercial load management programs. This section documents key findings and recommendations from the EM&V team's results for both commercial and residential load management programs.

Commercial Load Management Programs: Commercial load management programs are designed to manage kW use during summer peak demand periods. These periods are defined in most utility programs as 1:00 p.m. to 7:00 p.m., weekdays, June through September. These programs are based on performance and offer incentive payments to participating customers for voluntarily curtailing electric load on notice.

While each utility operates a unique load management program, there are many similarities among them. In general, a dispatch event may be called at the utility's discretion 30 to 60 minutes in advance of a curtailment event, which generally lasts one to four hours. In most cases, the utility reserves the right to call a certain number of curtailment events per season, ranging from 5 to 15, based on utility. Customers must meet several eligibility requirements, including but not limited to: (1) taking service at the distribution level, (2) meeting minimum demand requirements, and (3) being equipped with interval data recorder metering. Customers are not permitted to participate in other load management programs using the same curtailable loads at the same time period (i.e., *double-dipping*).

Participants can either curtail their contracted load during a load control event or opt-out if they wish not to participate. Participants receive an incentive based on the kW that they curtail during the event. Savings for kW and kWh are calculated by following the methodology described in TRM 6.0, and an incentive is given to a participant based on the amount of kW saved. This incentive amount is specified in an agreement with the utility when enrolling in the program and ranges from $15 to $50 per kW saved.

Residential Load Management Programs: Residential load management programs are designed to manage kW use during summer peak demand periods. Three of the nine Texas utilities offer a residential demand response program to their customers. Of the three, two of the programs utilize a smart thermostat control strategy, and the other utilizes direct load control devices. Incentives for these programs differ by whether the utility's service territory is part of the ERCOT market or not. Utilities in the ERCOT market receive an incentive based on the evaluated kW savings that are achieved during the load control season. In contrast, non-ERCOT utilities pay a flat enrollment incentive and a flat incentive per program year. Participants are given the opportunity to opt-out of a load control event.

Participants in two of the three residential programs are evaluated individually with the *high 3 of 5* method described in TRM 5.0. In contrast, the other is evaluated using the new deemed savings value for residential demand response smart thermostat programs. The availability of AMI meters dictates the methodology that a utility will follow to calculate savings.

All utilities define their control seasons as June 1 to September 30, with possible load control events happening within the window of 1:00 to 7:00 p.m. on weekday non-holidays for ERCOT utilities and 2:00 to 8:00 p.m. on weekday non-holidays for non-ERCOT utilities.

Residential programs in Texas have seen dramatic increases in evaluated kW savings over the past few years as participation has steadily increased. This increase in participation and savings can be attributed to the adoption and successful marketing of programs that utilize smart thermostats.

6.1 SUMMARY RESULTS

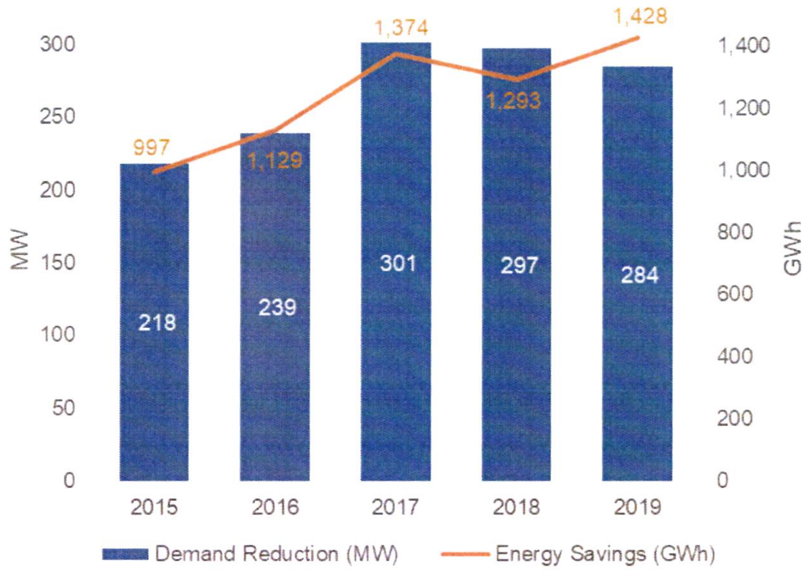
6.1.1 Savings

The total evaluated gross savings of the programs were:

- 284,085 kW (demand reduction), and
- 1,427,850 kWh (energy savings).

These results show a slight decrease compared to PY2018, by roughly 15 MW (15,000 kW). Figure 32 summarizes evaluated MW and MWh savings of all load management programs from PY2015 to PY2019.

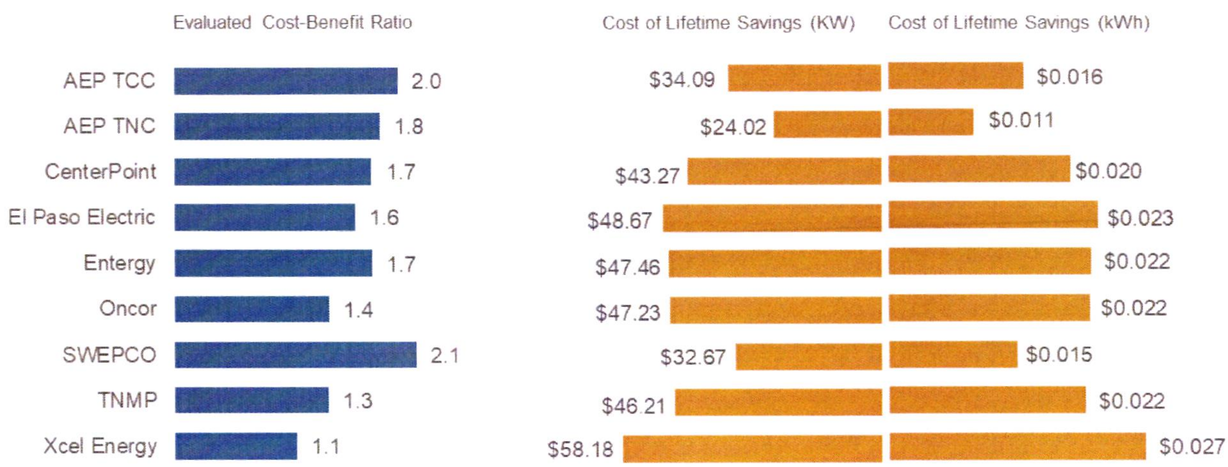
Figure 32. Total Statewide Evaluated Gross Demand Reduction and Energy Savings by Program Year—Load Management Programs



6.1.2 Cost-Effectiveness

Figure 33 summarizes the cost-effectiveness of each utility's energy efficiency portfolio based on evaluated savings of all load management programs in PY2019. All portfolios were cost-effective, ranging from 1.1 to 2.1. The cost per kW ranged from $24.02 to $58.18, and the cost per kWh ranged from $0.011 to $0.027. These costs provide an alternate way of describing the cost-effectiveness of a portfolio of programs. Those portfolios with a higher cost-effectiveness ratio will have a lower cost to acquire savings and vice versa.

Figure 33. Evaluated Cost-Benefit Ratio and Cost of Lifetime Savings—Load Management Programs PY2019



6.2 COMMERCIAL

This section summarizes the key findings and recommendations from the PY2019 evaluation of the commercial load management programs offered by the nine Texas utilities.

6.2.1 Program Overviews

The EM&V team applied the savings calculation methodology prescribed in the PY2019 TRM 6.0 on a census of records to calculate energy savings and demand reductions from interval meter data.

6.2.2 Key Findings and Recommendations

Key Finding #1: Utilities demonstrated strong capabilities to apply the TRM calculation method to savings.

PY2019 is the fourth year in which utilities and the EM&V team have applied the demand savings algorithm for commercial load management programs described in TRM 6.0. Now that the difficulties have been worked through in the previous years, and there is a mutual understanding of the *high 5 of 10* approach, the utility companies, implementers, and EM&V team were largely in agreement on final demand savings calculations.

Overall, the utilities applied the *high 5 of 10* method correctly to savings and matched the EM&V team's evaluated savings. The EM&V team noted, however, a minor discrepancy in one instance. When selecting baseline days using the *high 5 of 10* method for one site, six days were selected as baseline days because of a tie between two days. The EM&V adjusted the savings calculation to use the five highest loads closest to the event as baseline days.

Recommendation #1a: Continue implementing the demand savings algorithm described in the TRM and keep active communications with the EM&V team to resolve minor discrepancies in savings calculations. These recommendations will ensure consistency across utilities and enhance overall accuracy and transparency.

Recommendation #1b: In case of a tie between the days used to calculate the baseline, follow the TRM guidance of selecting the five highest loads closest to the event.

Key Finding #2: Texas commercial load management programs are effectively retaining commercial load participants.

Participation, as measured by the number of customers, has fluctuated annually in the past years but remained fairly stable over the past few years, with about 600 commercial participants. In 2019, participation increased to about 750, resulting in higher savings.

Recommendation #2a: Continue to assess the role of commercial load management programs as part of the utility's overall energy efficiency portfolio.

Key Finding #3: Minor discrepancies in savings calculation results were noted as a result of different rounding practices.

The EM&V team previously provided guidance on rounding practices to avoid minor discrepancies in savings calculations. The total program savings can be calculated by averaging the sum of sponsor-level savings or by adding the average sponsor-level savings. While, in theory, there should be no difference, the points at which rounding occurs can drive minor differences in calculation results. The EM&V team recommended that rounding occurs at the sponsor level for each event.

While rounding differences create only minor discrepancies in calculations, the differences have the potential to sum to a level that creates confusion or doubt. Using a standard practice or documenting differences will reduce the burden on the utilities and EM&V team (as discrepancies are investigated after initial calculations are developed) and will improve the consistency and transparency of savings calculations going forward.

Recommendation #3a: Data rounding should occur in only two instances—sponsor level savings and final program savings summaries. Without this standard practice, utilities should document when rounding is occurring in their calculations and inform the EM&V team.

Recommendation #3b: Update the load management guidance memo (TRM 7.0 Volume 5) to provide more details on when the rounding should occur during savings calculations.

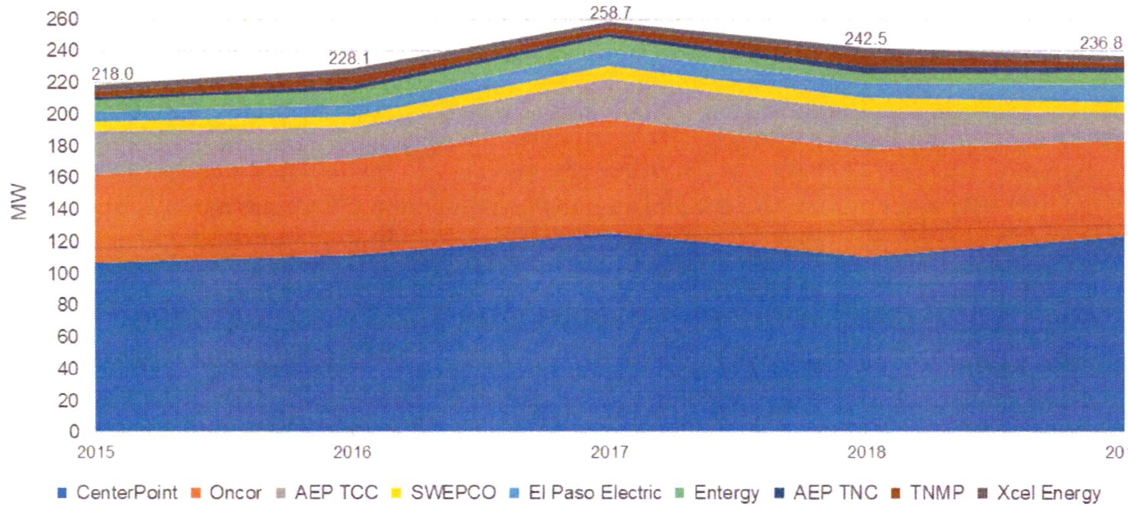
6.2.3 Impact Results

The total evaluated savings of all nine commercial load management programs were:

- 236,842 (demand reduction) kW, and
- 1,232,650 (energy savings) kWh.

These results show a slight decrease in savings compared to PY2018, by roughly 6 MW (5,680 kW). Figure 34 shows total kW savings from commercial load management programs by program year.

Figure 34. Evaluated Demand Savings of Commercial Load Management Programs (PY2015 – 2019)



Demand savings calculations from each utility were calculated largely the same as the evaluation calculations. There were no cases in which adjustments had to be made to individual meter savings calculations. This result supports the fact that both the EM&V team and the implementer and utilities are following the TRM algorithm for calculating saving precisely the same. While the TRM methodology was followed correctly by all utilities, realization rates for commercial load management programs were not 100 percent in PY2019. The reason for this discrepancy is that, when comparing individual meter savings for one of the commercial load management programs, it was found that the utility was following a conservative approach by not setting savings to zero in cases where the calculation methodology produced negative savings. Per TRM 6.0, in cases where the savings algorithm produces negative savings, the negative savings can be set to zero. As a result, commercial load management programs received a realization rate of 115 percent for kW and 109 percent kWh.

6.3 RESIDENTIAL

This section summarizes the key findings and recommendations from the PY2019 evaluation of the residential load management programs offered by three Texas utilities (El Paso Electric, CenterPoint Energy and Oncor). Other utilities did not offer a residential load management program.

6.3.1 Program Overviews

Two utilities calculated savings using interval meter data following the TRM 6.0 calculation methodology. The third utility used deemed savings from TRM 7.0.

6.3.2 Key Findings and Recommendations

Key Finding #1: Utilities demonstrated strong capabilities to apply the *high 3 of 5* method in TRM 6.0 to savings.

The two utilities that applied the *high 3 of 5* method to savings did so correctly and matched the EM&V team's evaluated savings.

Recommendation #1a: Continue implementing the demand savings algorithm described in the TRM and keep active communications with the EM&V team to resolve minor discrepancies in savings calculations—this will ensure consistency across utilities and enhance overall accuracy and transparency.

Recommendation #1b: Continue rounding data only at the event level or program year level. Residential programs have a very large number of participants, with the potential for rounding at the participant level driving substantial differences in savings at the event or program level. By consistently rounding only at the event level (summing individual participant savings), potential discrepancies between the EM&V team and utility calculations can be reduced.

Key Finding #2: There was still confusion surrounding language in the TRM 6.0 on how to apply the new deemed savings values.

PY2018 marked the first year in which utilities could calculate savings using a deemed saving approach if AMI meters are not installed on participating homes. One utility is following this approach. Upon evaluation of this program by the EM&V team and subsequent comparison to the utility calculated savings, the language in TRM 5.0 was found to be confusing regarding what qualifies a *participant*. The EM&V team, the utility, and the organization that produced the deemed savings value came to a consensus on how to apply the deemed savings value, and an evaluated savings result was agreed upon. This process involved excluding the meters that opted-out at the event-level and using a new deemed savings value (reflecting savings achieved by participants that did not opt-out of load control events) for future energy savings calculations.

Although the discussions and updates in TRM 6.0 clarified the exclusion of meters that opted out of the program, there is still confusion around partial participation. Per the TRM definition, participants are defined as *smart thermostats which participated no less than 50 percent time during the total event duration.* Therefore, partial participants that participated in an event for less than 50 percent of the event duration should be excluded from the savings calculation.

There will be clarifications in the next version of the TRM (8.0) to resolve this confusion and ensure a clear distinction between the different participation statuses at the event level (full participation, partial participation, or opt-outs) and how those should be treated in the savings calculations.

Recommendation #2a: Continue implementing the deemed savings value in TRM 7.0 and keep active communications with the EM&V team to ensure that there is a clear understanding of the TRM guidance and to resolve minor discrepancies in future program years.

Key Finding #3: Event-level savings calculations for the deemed saving approach can be simplified to avoid minor rounding discrepancies.

Per the TRM, event-level savings for the deemed saving approach are calculated by multiplying kW savings per device by the number of targeted devices and the participating ratio on that event. The EM&V team believes that the current calculation description has more complexity than needed, making it prone to rounding issues. Simplifying the description as follows will remove any rounding discrepancies:

"Event-level savings are calculated by multiplying kW savings per device by the number of participating devices."

Recommendation #3a: Update the TRM (Volume 2, section 2.2.10) to simplify the calculation of event-level savings.

6.3.3 Impact Results

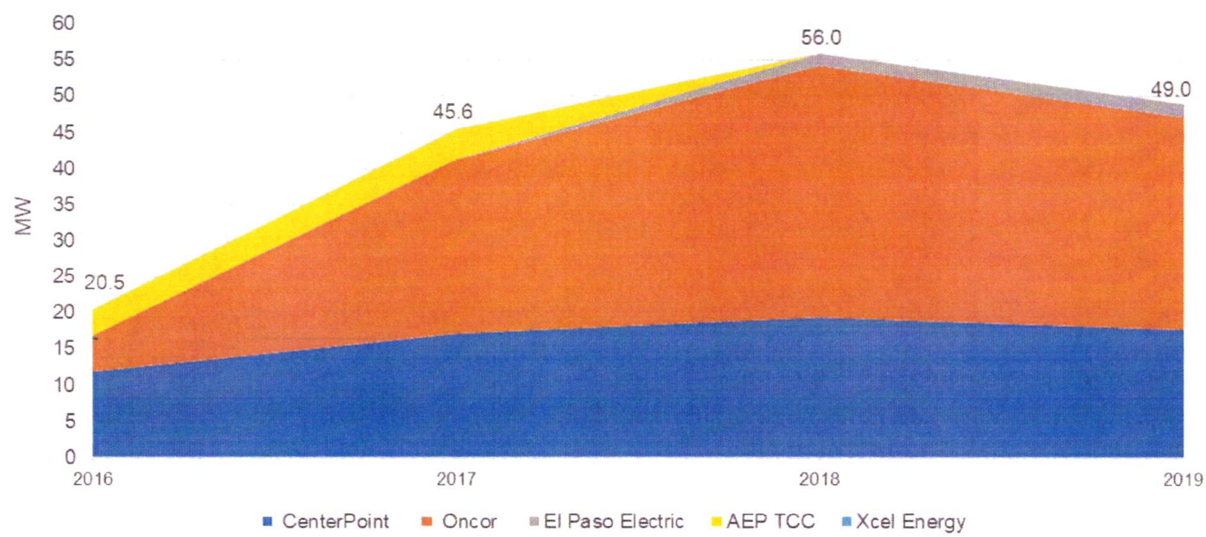
The total evaluated savings for the three programs were:

- 48,979 kW (demand reduction), and
- 239,897 (energy savings) kWh.

These savings are slightly lower than PY2018 by approximately 2,000 kW and 24,000 kWh.

Oncor's and CenterPoint's programs were in their fifth year of implementation in PY2019; El Paso Electric's program was in its second year of implementation. Figure 35 shows total kW savings from CenterPoint's and Oncor's residential demand response programs by program year. El Paso is not included at this time, as it is still operating as a pilot.

Figure 35. Evaluated Demand Savings of Residential Load Management Programs (PY2016 – 2019)



7.0 COVID CONSIDERATIONS

In March of 2020, COVID-19 was declared a global pandemic by the World Health Organization. Texas responded first locally with *stay home/work safely* policies at the city- and county-levels, followed by the issue of statewide orders by Governor Abbot. Texas' *stay home/work safely* order expired April 30, 2020, and Texas began a phased re-opening intending to minimize the spread of COVID-19 while re-opening the economy.[19] At the time of the writing of this report in July 2020, Texas has been experiencing COVID-19 spikes, and Governor Abbot has paused the re-opening process. The situation continues to evolve dynamically.

Because one of the primary objectives of this report is to provide recommendations for 2021 programs, the EM&V conducted research in May–June 2020 to provide the context of the impacts of the pandemic on the energy efficiency programs. The EM&V director interviewed utility program managers and directors to characterize how utilities are responding to COVID-19 in their energy efficiency portfolios. This information is complemented with information from residential service provider surveys and secondary research of energy efficiency developments across the country in response to COVID-19.

7.1 KEY FINDINGS AND RECOMMENDATIONS

Looking across these various sources of data, the EM&V team offers the following key findings and recommendations:

Key Finding #1: All utilities believe they will meet 2020 commercial goals.

Utilities reported that strong project pipelines before the pandemic and customers taking advantage of unoccupied facilities to install energy efficiency projects are the primary drivers of continued commercial program success. The pandemic has slowed down some projects due to supply chain issues, and some utilities are predicting a more pronounced *hockey stick* effect of project closings in the last quarter of 2020. However, all utilities still believe they will meet or exceed their goals.

While utilities have been primarily focused on meeting the 2020 program challenges, they have given some thought to 2021. In general, it is believed that the programs will continue to face challenges in 2021 on the commercial side, whether it is pandemic safety concerns or economic impacts from the pandemic such as state or local government budget cuts or business layoffs and closures.

Recommendation #1a: Utilities who have already met commercial 2020 goals may want to encourage applicable projects to roll into 2021 so that a strong pipeline is established for the next program year given uncertainty is still expected.

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[19] Texans helping Texans, The Governor's Report to Open Texas, April 27, 2020, https://gov.texas.gov/uploads/files/organization/opentexas/OpenTexas-Report.pdf

Key Finding #2: Small businesses have become more difficult to serve during the pandemic.

A combination of small business closures and low profit margins exacerbated during the pandemic, and other concerns generally have small business programs struggling to meet 2020 goals.

The secondary research found that some commercial programs across the country are exploring ways to deliver lighting, controls, and HVAC upgrades in partnership with COVID-19 renovation projects, such as dividers for open-space offices and improved air quality systems.

Recommendation #2a: Explore low-cost/no-cost measure solutions specifically tailored to small businesses as well as strategies implemented elsewhere in the country, such as leveraging COVID-19 remodels with energy efficiency upgrades.

Key Finding #3: While the majority of utilities believe they will meet 2020 residential goals, they have generally seen more residential program challenges during the pandemic.

Utilities who believe they will meet residential goals in 2020 generally credit their strong network of service providers for continued residential program success during the pandemic. In contrast, one utility who feels they may not meet 2020 residential goals cite limitations in their contractor infrastructure (i.e., lack of technology aptitude). Furthermore, multifamily and single-family projects complemented each other for utilities that have both sectors to serve, but not all utilities do.

Unlike commercial, there were fewer overarching themes statewide. Instead, residential challenges and successes are unique to each utility territory. Some utilities reported increased demand for HVAC with no demand for envelope measures, while others reported the reverse. Two of the nine utilities reported complete residential program shutdowns for a period of time; other utilities reported no shutdowns or slowdowns. The ERCOT utilities that coordinate with federal weatherization agencies did report shutdowns by the federal agencies that halted LI programs for a time.

The Texas utilities with upstream or midstream programs expanded those options somewhat to offset decreases in customer-direct programs. Moreover, utilities with new homes programs reported no decreases in activity. The literature review also found other utilities throughout the country emphasizing point-of-sale programs, online marketplaces, and refrigerator recycling programs where appliances are left curbside over in-house retrofits. Smart thermostats were found to be a popular item during the pandemic for the Texas utilities and other utilities throughout the country. Surveyed residential service providers recommended increased incentives and outreach during the pandemic.

Recommendation #3a: Utilities may want to consider complementing traditional in-home retrofit services with other program delivery methods such as upstream and midstream venues or self-install options by homeowners and multifamily maintenance staff.

Key Finding #4: Utilities are employing remote QA/QC practices.

All interviewed utility staff have been working from home since the pandemic began. They are employing a range of remote QA/QC practices, including in-depth engineering desk reviews, phone audits, virtual inspections provided through video, and expanded photo documentation. Remote QA/QC was also found to be the standard pandemic response in the secondary review of other utilities. One Texas utility in an area that was not experiencing a COVID-19 spike at the time of the interview has begun doing on-site inspections again in local areas. Some other utilities said they were looking forward to getting back on-site.

Both the Texas utilities and the secondary review found that some utilities are thinking toward the future, and if any of the new practices being deployed—even temporarily—will be beneficial to continue. The benefits of these new practices were discussed regarding conducting virtual inspections, especially for utilities with large service territories and distances between projects. Remote inspections could provide future cost savings if found to be effectively verifying savings.

Recommendation #4a: The 2020 EM&V should assess utility project QA/QC and documentation in terms of what was able to be feasibly accomplished remotely during the pandemic. Additionally, the 2020 EM&V's review of remote QA/QC should include an assessment of new practices to recommend if there is value in continuing any of these new practices. For example, successful virtual QA/QC processes may decrease on-site QA/QC inspection costs in the future, or utility-enhanced QA/QC desk reviews may decrease errors found during the EM&V reviews.

Key Finding #5: Utilities have taken different approaches to health and safety during the pandemic.

While all utilities report their company has implemented health and safety practices for their staff, guidance provided to service providers has varied. The most common approach is the view that service providers are businesses that have staff and customer safety at the top of mind and are implementing proper practices. In these cases, utilities are available to answer questions or provide help if requested. Utilities ask service providers to follow the local guidance in place. The less common approach found in Texas was a required health and safety training for service providers. One utility said the lack of health and safety protocols specific to the programs has been a major obstacle to their programs' activity. While most surveyed residential providers felt they were doing well in employing health and safety measures, responses did indicate receptivity to additional guidance from the utilities.

Recommendation #5a: Utilities may want to consider providing links to readily-available health and safety protocols from reputable sources, including national energy efficiency organizations and the Texas Department of State Health Services.

Key Finding #6: To date, customer complaints have not been an issue during the pandemic.

Utilities report that customers are expressing gratitude for program services during the pandemic as opposed to complaints. One utility has been following up on their service providers' health and safety practices and has found that the overwhelming majority of participants are reporting service providers are doing well in their safety practices. At the same time, utilities report that an essential piece of customer satisfaction during the pandemic is that they are not pushing customers out of their comfort zone if they want to cancel or delay a planned project. Utilities are only going into homes and facilities when the customer is comfortable with services being provided on-site.

Recommendation #6a: If not already doing so, utilities should consider including a health and safety question in ongoing program customer satisfaction surveys or other types of follow-up with customers on how well their service providers are performing during the pandemic.

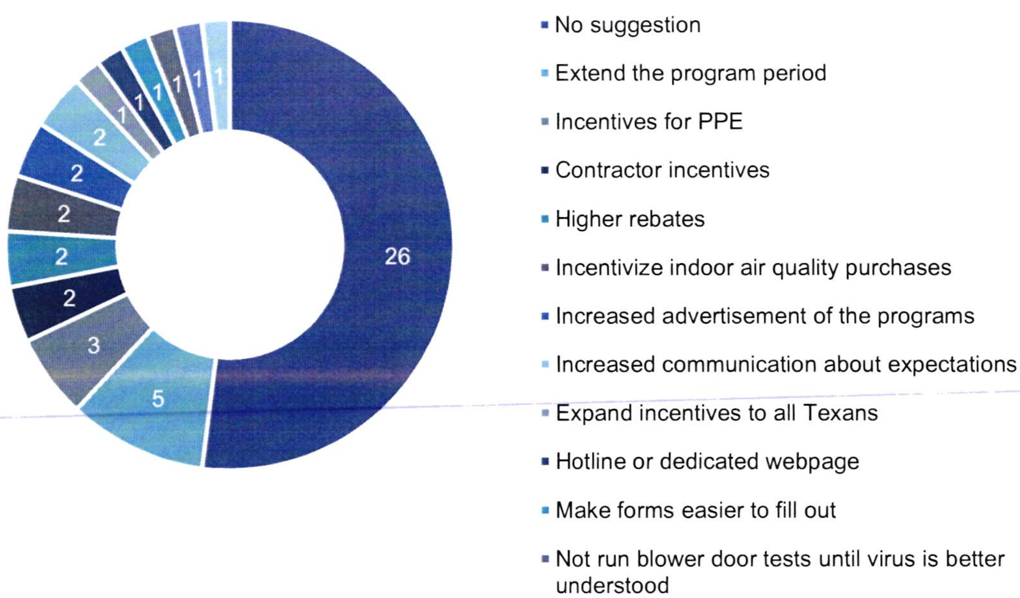
7.2 SERVICE PROVIDER FEEDBACK

The EM&V team surveyed residential service providers that participated in SOP, MTP, or HTR retrofit programs in 2019. While the purpose of the survey was to gather process information to understand how the programs are operating from service providers' perspectives, questions were also added to learn how the utility could help them during the COVID-19 pandemic.

Of the 50 service providers surveyed, most said they would not need additional support to implement the program once social distancing is eased (36 respondents). Half of the respondents did not have any suggestions for ways their utility can help during current *stay home/work safely* practices. The top three recommendations for providing help, either while the *stay home/work safely* order is active, or after, is to extend the program period, increase incentives, and increase marketing.

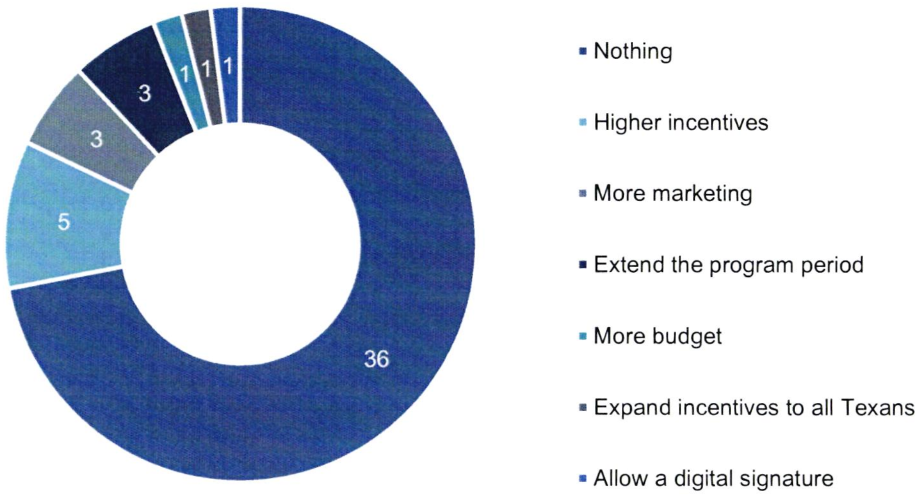
A total of 50 service providers were asked, "What support or program options would you like to see in the Texas utility programs to help your firm continue to implement energy efficiency projects given the current COVID-19 *stay home/work safely* practices?" A little over half of the respondents (26 respondents) said they had no suggestions for additional support. Five respondents said extending the program period would be helpful since projects are taking longer, given the slowdowns the COVID-19 has caused. Three said receiving incentives for personal protective equipment (PPE) would be helpful, followed by providing contractor incentives (2 respondents), higher rebates (2 respondents), incentives for air quality equipment (2 respondents), additional marketing (2 respondents), and increased communications to discuss program expectations (2 respondents). The full list of suggestions mentioned is shown in Figure 36 below.

Figure 36. Suggestions for Support or Program Options to Help Implement Projects During COVID-19 (n=50)



The same 50 service providers were also asked, "What support or program options do you think your firm will need to continue to implement projects after the easing of social distancing?" Most respondents said they would not need support after the easing of social distancing (36 respondents); five respondents said higher incentives would be needed to continue implementing projects; three said more marketing is needed; and three mentioned extending the program period. Also mentioned was increasing the program budget, offering the program to all Texas residents, and allowing for a digital signature when submitting paperwork.

Figure 37. Suggestions for Support or Program Options to Help Implement Projects During COVID-19 (n=50)



7.3 UTILITY PROGRAM STAFF FEEDBACK

The objective of the interviews was to characterize how utilities are responding to COVID-19 in their energy efficiency portfolios. The EM&V director conducted the interviews between June 15 through June 30, 2020. The interviews were semi-structured. Questions were not necessarily asked verbatim but followed the flow of the conversation with interviewees. Interviews ranged from 20 to 40 minutes in length. Specific interview objectives included:

- understand recent or proposed changes for programs due to the pandemic;
- characterize how program operations, including staffing, QA/QC, engagement activities, measure mix, and delivery strategies have changed in response to COVID-19; and
- identify strategies that can safely support program success as well as opportunities for improvement and program challenges.

Staff feedback was the primary foundation of the key findings and recommendations above, as results were synthesized across utilities.

7.4 SECONDARY REVIEW

Like all parts of our economy, energy efficiency programs have been up against substantial challenges as a result of the COVID-19 pandemic. Nonetheless, programs across the country have continued to provide at least limited services, some getting back into the field, and with leaders creatively pivoting to meet the challenge of a rapidly changing environment. By the end of March 2020, at least 19 states halted all retrofits to low-income homes under the Federal Weatherization Assistance Program. The Building Performance Association[20], which represents 9,500 home and building performance contractors, reported that virtually all residential energy efficiency work was suspended by utilities, states, service providers, and small businesses. While residential energy efficiency programs were hit the hardest, C&I energy efficiency programs also saw a substantial reduction in activity. As a result, utilities across the country took a variety of actions to try to continue to meet energy efficiency goals and lessen the impact on the energy efficiency workforce. Those actions generally fell into these categories:

- vendor communications and support,
- pipeline and backlog development,
- virtualization, and
- education, and marketing.

Below we discuss the various activities that utilities implemented within these categories.

Vendor Communication and Support

Program contractors and trade allies have been hit hard by the restrictions on direct customer contact. Some programs have been using this time to train program staff and contractors who are unable to work. Such training includes typical professional development and skills, as well as training on new guidelines and practices to ensure health and safety. For example, state officials in New York have developed guidelines and are coordinating free online training opportunities for clean energy contractors in response to the pandemic. Similar training and supporting resources are available to energy efficiency contractors serving utilities in Massachusetts, Rhode Island, Connecticut, and New Hampshire, as well as others across the country.

Pipeline and Backlog Development

A lot of program work can happen without direct customer contact, including planning and developing projects. Many types of energy efficiency measures can be installed, and many projects can move forward while adhering to public health guidelines. For example, some programs have targeted vacant schools and offices (where applicable) and mechanical rooms. One emerging idea has been for programs delivering lighting, controls, and HVAC upgrades to partner with COVID-19 upgrade projects, such as dividers for open-space offices and improved air quality systems.

Virtualization

Most utilities continued some programs while others paused completely; however, there was a near-universal suspension of on-premise energy efficiency programs. Instead, utilities moved to:

- accepting prescriptive applications, point-of-sale, and trade ally incentives (especially for emergency replacement or repair);
- emphasizing online marketplaces;
- continuing appliance recycling with curbside pick-ups;
- adjusting messaging for behavioral/home energy report programs;
- shifting to or creating virtual home audit programs; and
- using or ramping up virtual tools for commercial pre- and post-inspections.

[20] https://www.building-performance.org/who-we-are

Some utilities made incentive adjustments, including increasing incentives in recognition of economic hardship (or considering incentive increases once restrictions are lifted). Some utilities increased insulation rebates to 100 percent, and some extended or relaxed rebate deadlines.

On the residential side, utilities moved to virtual home audits, collaborating with technicians and customers. To perform virtual audits, some programs used facilitation tools such as FaceTime, Skype, etc., and some used lower-tech options such as phone calls and sending pictures. In many cases, customers took measurements and video for technicians. The virtual assessments typically have lasted 45 to 90 minutes each and have been free to customers. On the commercial side, programs have also been using remote and virtual audits and pre-inspections to move projects forward and increase cash flows. Some programs completed in-person *napping campus tours*, as it was acceptable (and sometimes easier) to do some site walkthroughs while buildings were not operational.

Education and Marketing

With so many people staying at home, programs have taken advantage of this unique opportunity to engage with their customers to educate, inform, and motivate them to take action to reduce their energy use and save money. Utilities in several states have sent their customers specific advice on saving energy while they are at home during the day. Programs have expanded and created new online resources, tools, and messages to increase their outreach to customers, identify and take advantage of immediate energy savings opportunities, and plan for longer-term improvements. For example, Xcel Colorado paired virtual audits with deliveries of no-cost do-it-yourself kits and virtual installation support, as well as follow-up virtual visits to confirm installations and plan the next steps. Consumers Energy is providing 100,000 smart thermostats to its customers during the pandemic through its online energy marketplace.

Most utilities have continued their home energy reports (HERs) program but have adjusted the messaging. For example, messaging has focused on the fact that behavioral change is free and easy to implement, and that efficiency is needed in light of higher residential occupancy. Some messaging has acknowledged COVID-19 and addressed customer concerns around topics such as power cutoffs. Other messaging has provided:

- specific advice for people spending more time at home and teleworking;
- tips that intersect both health and energy (e.g., washing hands and reducing hot water usage); and
- recommendations on easy, low-cost, or no-cost suggestions that customers can do on their own.

These messages have often increased in frequency, especially using email and online or digital tools (i.e., driving customers toward online account management tools). Similarly, some utilities have increased the emphasis on promoting programs through digital channels (e.g., blogs, email, social media). They have also used analytics to create targeted messaging, in part to build project pipelines and also to identify energy-burdened households, identify key drivers of load, and recommend and promote appropriate behavioral programs.

Table 34 highlights a few utility-specific examples of pandemic response to energy efficiency program implementation.

Table 34. Utility Response to COVID-19

Utility	COVID-19 Response

DTE Energy (DTE)	• DTE's programs that have direct homeowner and business contact were shut down (Appliance Recycling and Direct Install programs, in-home and in-business inspections, etc.). Even though retailers have remained open (e.g., big box stores, hardware stores), programs have suspended in-store outreach to them.
	• Programs and implementers have been continuing to process rebates, send HERs, and work through midstream programs (with contractors that are still running or operating), as there are contractors still working and offering no-contact visits.
	• DTE's call center continued to operate (remotely), though the implementer noted that call volume decreased dramatically (DTE call volume was down about 40 percent through April 2020).
	• DTE asked their implementers to begin working on recovery plans once *stay at home* orders are lifted. Because this is unchartered territory, no one knows if there will be pent-up demand or if it will kill demand. There is also concern that small businesses will not have funds to invest in energy efficiency for a while.
	• DTE has an online marketplace that has been holding steady—volume is up, and they are trying to move product through that channel. DTE had noted that the sales of actual items were up 35 percent, but dollars were less.
	• DTE focused its marketing messaging on promoting energy efficiency and energy education, specifically about how energy efficiency can help mitigate high bills while working from home.
	• DTE noted that no one is sure what the new *normal* will be, and who will drive that (contractors, the Center for Disease Control, etc.).
	  ○ Liability is going to be a concern, as even once the *stay at home* orders are lifted, COVID-19 will still be around.
	  ○ Programs will need to tie in with industry associations and what they decide to do, it is not the utility's place to impose rules for contractors.
	• The other big concern for DTE and implementers has been the performance metrics and incentives that are based on those, as well as the regulations that are in place for utilities (settlement agreements, etc.). DTE has encouraged everyone to do the best they can and document everything.

Utility	COVID-19 Response
Energy New England	• Efficiency audits conducted by video have helped municipal cooperative Energy New England (ENE) to avoid laying off staff, and officials say customer enthusiasm for the new approach may signal a permanent change in how business is conducted. • ENE provides efficiency services and other products to 25 municipal utilities in the Northeast and has been experimenting with virtual energy audits to keep workers on board and maintain a pipeline of projects for when the economy reopens. The group is exploring offering similar services to small business customers. • ENE engineers use either Facetime or Google Duo to complete the virtual audits. While it takes a bit more preparation to walk customers through the audit, they have seen more engaged responses from homeowners, though also note that the technology piece is not for everyone. So far, all homeowners who have completed ENE's virtual audit have indicated they intend to move forward with recommended changes and retrofits. The process typically takes between 45 and 90 minutes to complete, with the customer taking some measurements and capturing images that an efficiency engineer would typically do. • So far, ENE has managed to retain workers that specialize in efficiency work, but companies that do the actual construction work are facing bigger challenges.
Eversource	• The Eversource service territory spans three states—Connecticut, Massachusetts, and New Hampshire. By the end of March 2020, Eversource had suspended in-home or on-premise services across all of its service territories. Restarting those programs all depends on re-opening plans. During the *stay at home* order, Eversource provided the following vendor communications and support. o created FAQs in all three states, o provided information on federal and state assistance programs, o supported joint webinars which summarize these federal and state assistance programs, o supported the Connecticut Technical Advisory Committee working group with the Connecticut Department of Energy and Environmental Protection (DEEP), o supported public input sessions (through DEEP), and o organized four state training plans for residential and commercial contractors through online learning modules (a joint effort with Connecticut, Massachusetts, New Hampshire, and Rhode Island and their PAs). • For residential and commercial programs, Eversource: o made progress payments or partial payments for measures installed or percent complete; o extended or relaxed rebate deadlines; o continued to process rebate applications; o continued to review and approve projects in the pipeline short of in-home and on-premise services; o developed enhanced offerings for when full program activity resumes (i.e., increased incentives for HPs, insulation); and o conducted virtual inspections and assessments through videos, pictures, etc.

<table>
<tr><th>Utility</th><th>COVID-19 Response</th></tr>
<tr><td>Massachusetts Program Administrators (Mass Saves)</td><td>

In Massachusetts, the state's Department of Energy Resources suspended the majority of on-premise efficiency work but also shifted to more remote and virtual procedures, including virtual home energy assessments and virtual pre- and post-inspections for projects.

The state's Mass Save program has offered virtual home energy assessments through its vendors for residential customers and has been looking into options for virtual small business audits.
Mass Saves also waived the co-pay and is offering free training for the contractor community to continue to strengthen the workforce and keep contractors engaged. Additionally, measures and projects were identified that could be re-initiated when determined appropriate.
Due to public health and safety concerns, PAs decided to suspend on-premise energy efficiency activity:

PAs will not pay incentives associated with contracted on-site services during this period.
Exceptions will be permitted on a case-by-case basis for safety or emergencies.
PAs anticipate the temporary suspension will remain in place for the foreseeable future.
PAs will consider resuming on-premise services based on guidance from federal, state, and local public health officials and after the development of appropriate health and safety protocols.

Other energy efficiency services remain active, including:

online audits;
upstream and point-of-sale offerings;
retail rebates;
active demand response;
trade-ally-driven C&I incentives;
virtual pre- and post-inspections for C&I projects (in some limited cases);
refrigerator recycling pick-ups (permitted, as long as the refrigerator is left outside);
HEAT Loan availability (on-premise Home Energy Assessment (HEA) requirement temporarily suspended); and
Developing other remote options, including accelerating virtual HEAs.

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Utility	COVID-19 Response
Seattle City Light	• Seattle City Light has been taking steps to ensure efficiency contractors get paid for work completed or work that is in progress. The utility has been looking at projects that they believe to be awaiting payment, or close to payment, and are trying to expedite that. • In some instances, work is being verified through video or photographs or screenshots of energy management system outputs. Images from Google Maps have been used to verify pre-existing conditions of buildings. • Despite the creative efforts, Seattle is forecasting a seven percent reduction in energy savings this year. However, that reduction could be made up in the future if federal legislators can include efficiency measures in future stimulus efforts. • Seattle City Light typically covers 50 to 70 percent of the upfront cost of efficiency work. Federal funding could push that to 100 percent, similar to what was done during the Great Recession.

Are the new practices that are being deployed, even temporarily, beneficial to the construction of energy-efficient buildings? Will they continue to be used after the pandemic recedes? DTE, and other Michigan utilities and key stakeholders, have said they believe that things will be different for quite a while. DTE believes that how programs are implemented may change forever. Only time will tell, but there can be benefits to conducting virtual inspections, especially for utilities with large service territories and distances between projects. Remote inspections can provide cost savings by performing inspections and verifying the efficiency requirements in the building codes, saving time and money in the process. Physical building inspections will resume for all types of buildings at some point. Still, some of the innovations in M&V, building inspection, and code enforcement brought about by the COVID-19 pandemic are likely to persist. These innovations are enabling utility programs to ensure safe, resilient, and energy-efficient buildings in any type of environment.

TECHNICAL APPENDIX 1 RESIDENTIAL RETROFIT CONSUMPTION ANALYSIS

Introduction

This Technical Appendix provides the methodology and findings associated with the residential retrofit consumption analysis that was conducted as part of the PY2019 EM&V effort. The analysis aims to estimate the impact of the Residential Standard Offer Program (RSOP), the Hard-to-Reach Standard Offer Program (HTR SOP), and the Low-Income (LI) program, at both the program and measure level.

Table 35 presents a list of acronyms used throughout this document.

Table 35. Acronym Definitions

Acronym	Definition
RSOP	Residential standard offer program
HTR SOP	Hard-to-reach standard offer program
LI	Low-income program
TRM	Texas Technical Reference Manual Version 6.0
ASOS	Automated Service Observing System—the name of the network of real weather stations
TMY3	Typical meteorological year 3
PRENAC	Annual weather-normalized consumption in the pre-period
SEER	Seasonal energy efficiency ratio
CDD	Cooling degree day
HDD	Heating degree day
PDPF	Peak demand probability factor

The Data

We have four sources of data:

- **Program Tracking Data.** We received program tracking data that contained account numbers, participation dates, addresses, and measures received. Program tracking data also include the reported Texas Technical Reference Manual Version 6.0 (TRM) savings estimates for each measure received, the utility associated with the account, and the program in which the account participated.
- **Meter/Consumption Data.** We received 15-minute interval data from Oncor, CenterPoint, AEP TCC, AEP TNC, and TNMP for the period between January 1, 2017, and January 1, 2020. This data contained an account number, timestamp, and kWh consumption for each 15-minute interval. Some utilities provided data before the validation, editing, and estimation (VEE) process, while others provided post-VEE data.
- **Texas Weather Data.** This data was retrieved from the Automated Service Observing System (ASOS) network.[21] This data contained the hourly temperature readings for the period between January 1, 2017, to January 1, 2020. We used data from the station

[21] https://mesonet.agron.iastate.edu/request/download.phtml?network=TX_ASOS

closest to each TMY3 station, for a total of 59 weather stations. For more information on the Texas weather data, see Appendix 1-A: Supplemental Information on Weather Data.

- **Texas Typical Meteorological Year 3 Data (TMY3).** This file contains hourly temperature readings for the period 1991 to 2005 and was used by NREL to construct the typical weather for one year. Weather data was constructed by selecting each month that represents the most typical weather between 1991 and 2005 to form one full calendar year. This data was used to normalize energy use in the pre- and post-period of the analysis. There are 61 TMY3 stations; only 59 ASOS stations were used due to insufficient data at one station and one station being the closest ASOS station to two separate TMY3 stations. Due to a recent change, the link to this data source is no longer maintained.

Participant Group:

The participant group is defined as customers who participated in the RSOP, HTR SOP, or LI programs during the 2018 calendar year. We use the terms *participant group* and *treatment group* interchangeably.

Comparison Group:

We use a quasi-experimental design to estimate the effects of the programs on energy consumption. In this approach, we want to compare the change in energy use among the treatment group before and after their participation in the program (change due to the program) with the change in energy use over that same period among an equivalent group that did not participate. Change in energy use for the latter reflects what would have happened absent the program. Defining an equivalent comparison group is critical to establish internal validity. We follow the recommendation in the Uniform Methods Project for programs with non-randomized participant populations spanning multiple years and construct a comparison group of future participants.[22] Specifically, we define the comparison group as customers who participated in one of the same programs (RSOP, HTR SOP, or LI) in 2019. Comparing pre- and post-energy use of PY2018 participants with the pre- and post-energy use of PY2019 participants allows us to assess the effects of the program.

Final Participant and Comparison Group Samples:

This section describes the screening criteria used to qualify accounts for the analysis. We apply screening criteria to the analysis population to exclude accounts with data quality issues that could bias model results. The 2015 consumption analysis informs much of the screening criteria. We exclude accounts as described below (Appendix 1-B: Screening Criteria Details presents more detailed information on the screening requirements).

- Accounts that participated in both 2018 and 2019. If there were more than 12 months between the 2018 and 2019 participation dates, the account was still used as part of the treatment group.

- Accounts that have solar interconnect agreements. Since these accounts produce some or all of their own electricity, we would not have complete consumption data.

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

- Accounts where meter data was missing entirely. It is not possible for us to include these accounts in the analysis.
- Accounts where the earliest or latest meter reading date was less than 365 days from the participation date. In other words, accounts are excluded when the pre- or post-installation period was less than one full year. Using one full year of pre- and post-data is standard practice and allows us to observe consumption in every season.
- Accounts that were missing more than the equivalent of one total day of consumption data (i.e., missing more than 96 15-minute meter data readings across the entire 730 days (365 pre- and 365 post-program, not necessarily 96 consecutive 15-minute readings). This rule allows us to retain accounts with relatively small amounts of missing data, thus preserving the size and heterogeneity of the analysis group while excluding those where large amounts of missing data could bias model coefficients.
- Accounts with at least one week (672 15-minute meter data readings) of continuous meter readings of zero kWh or at least one total month (2,880 15-minute meter data readings) of meter readings of zero kWh, in aggregate. Long streaks or large amounts of meter readings of zero kWh indicate periods of vacancy, meter reading failure, or other issues that could bias model results. Meter readings of zero kWh are somewhat common (about 98 percent of accounts in the treatment group have at least one zero kWh reading); therefore, retaining accounts with some zero kWh readings was essential to preserve the size of the analysis group. Appendix 1-B: Screening Criteria Details provides more detail on this screening step.
- Accounts with changes in consumption from the pre- to post-period in excess of ±70 percent. Changes in annual electricity usage of this magnitude are uncommon and are likely the result of non-programmatic effects.
- Accounts in which the estimated TRM savings were less than one percent or greater than 100 percent of the pre-period consumption. These accounts are outliers that will show very small savings due to a minor project or have estimated savings that are not actually possible.
- Accounts with total usage that was excessively high or low in the pre- or post-period (less than 1,000 kWh or greater than 70,000 kWh); these accounts are outliers. The average consumption in the pre-period is about 15,000 kWh, and these accounts represent uncommon situations of drastically high or low consumption, which could influence model results.

Table 36 shows the number of accounts represented by each utility in each program. Totals across programs may be slightly different than the total number of treatment group or comparison group accounts, as 38 treatment group and 294 comparison group accounts were noted as participating in multiple programs. Where analysis was conducted on individual programs, those accounts are included in both programs; however, an analysis conducted on all programs simultaneously included one instance of the account to avoid double counting.

Table 36. Accounts by Utility, Program, and Treatment/Comparison Status

Utility	RSOP		HTR SOP		LI	
	Treatment	Comparison	Treatment	Comparison	Treatment	Comparison
AEP TCC	2,498	2,648	797	802	126	36
AEP TNC	399	260	186	116	25	25
CenterPoint	229	56	367	58	717	0
Oncor	10,016	7,041	4,899	6,264	859	996
TNMP	846	981	252	190	81	217
Total	**13,988**	**10,986**	**6,501**	**7,430**	**1,808**	**1,274**

Table 37 provides details on the number of accounts removed from the analysis for reasons detailed previously, and Table 38 shows overall sample attrition and retention information by program and utility.

Table 37. Detailed Sample Attrition, Treatment and Comparison Groups

Screen	Treatment		Comparison	
	Accounts Remaining	Percentage Remaining	Accounts Remaining	Percentage Remaining
Census	33,567	100.0%	29,785	100.0%
In treatment and comparison	33,219	99.0%	29,785	100.0%
Solar	32,975	98.2%	29,700	99.7%
No meter data	32,963	98.2%	28,237	94.8%
Meter min/max <1 year	32,200	95.9%	28,012	94.0%
Missing data	28,783	85.7%	23,917	80.3%
0 kWh data	23,042	68.6%	19,816	66.5%
Percent change >70%	22,690	67.6%	19,429	65.2%
Project size <1% of pre-program	22,295	66.4%	19,429	65.2%
Total usage outlier	22,259	66.3%	19,396	65.1%
Final	**22,259**	**66.3%**	**19,396**	**65.1%**

Table 38. Sample Attrition by Program and Utility*

Program	Group	Account Attrition	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP
RSOP	Treatment	Original accounts	6,170	854	493	12,110	1,270
		Final accounts	2,498	399	229	10,016	846
		Percentage retained	40.5%	46.7%	46.5%	82.7%	66.6%
	Comparison	Original Accounts	5,637	549	295	7,834	1,312
		Final Accounts	2,648	260	56	7,041	981
		Percentage Retained	46.8%	46.7%	13.5%	88.8%	74.8%
HTR SOP	Treatment	Original Accounts	1,729	364	755	6,556	347

Program	Group	Account Attrition	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP
		Final Accounts	797	186	367	4,899	252
		Percentage Retained	46.1%	51.1%	48.6%	74.7%	72.6%
	Comparison	Original Accounts	1,585	310	552	8,755	270
		Final Accounts	802	116	58	6,264	190
		Percentage Retained	49.8%	36.9%	10.5%	71.5%	70.4%
LI	Treatment	Original Accounts	453	60	1,462	1,044	218
		Final Accounts	126	25	717	859	81
		Percentage Retained	27.8%	41.7%	49.0%	82.3%	37.2%
	Comparison	Original Accounts	219	72	1,441	1,370	266
		Final Accounts	36	25	0	996	217
		Percentage Retained	10.1%	34.7%	0.0%	72.6%	81.6%

*Note Totals that do not match other totals in this report are due to accounts that participated in multiple programs

Final Measure Distributions:

Table 39 shows the distribution of measures for the participant group accounts that were used in the analysis. As a guide to Table 39, 45 percent of the treatment group accounts that were included in the analysis of the RSOP received an air infiltration measure. In comparison, 54 percent of the population of 2018 RSOP participants received an air infiltration measure. With a similar format to Table 39, Table 40 and
Table 41 show comparisons of the measure frequency and average estimated TRM savings between the treatment analysis sample and the treatment population. These tables give context for understanding model results. The distributions of the measures and the average TRM savings are similar across the analysis sample and population, indicating the sample reflects the population. The main difference is that estimated heat pump savings are slightly higher in the analysis sample than in the population. Other differences in estimated savings can be attributed to the number of accounts being very small, making the difference between population and sample mean TRM savings volatile.

Table 39. Final Measure Distribution (Participant Sample vs. Participant Population) *

Category	Measure	Percentage of Sample			Percentage of Population		
		RSOP	HTR SOP	LI	RSOP	HTR SOP	Low Income
Shell	Air Infiltration	45%	68%	10%	54%	67%	8%
	Ceiling Insulation	13%	34%	17%	13%	30%	18%
	Floor Insulation	0%	<1%	<1%	0%	<1%	<1%
	Solar Screen	<1%	<1%	<1%	<1%	<1%	<1%
	Wall Insulation	<1%	<1%	5%	<1%	<1%	3%
	Windows	<1%	<1%	2%	1%	2%	1%
HVAC	AC	26%	<1%	<1%	19%	<1%	<1%
	Duct Sealing	14%	12%	1%	23%	17%	1%
	Heat Pump	18%	10%	81%	15%	14%	83%
	Window AC	0%	0%	<1%	0%	0%	<1%
Final Accounts		**13,988**	**6,501**	**1,808**	**20,897**	**9,751**	**3,236**

*Note: Percentages do not total to 100 percent since an account could have more than one measure.

Table 40. Final Measure Frequency (Participant Sample vs. Participant Population)

Category	Measure	Frequency (Sample)			Frequency (Population)		
		RSOP	HTR SOP	LI	RSOP	HTR SOP	LI
Shell	Air Infiltration	6,306	4,445	173	11,274	6,510	244
	Ceiling Insulation	1,778	2,222	300	2,719	2,888	571
	Floor Insulation	0	1	1	0	1	1
	Solar Screen	2	2	15	4	4	18
	Wall Insulation	3	7	97	3	15	108
	Windows	19	5	28	263	235	43
HVAC	AC	3,579	17	10	3,900	45	24
	Duct Sealing	1,970	775	21	4,722	1,640	47
	Heat Pump	2,496	659	1,467	3,185	1,323	2,700
	Window AC	0	0	1	0	0	1
Total Measures		**16,153**	**8,133**	**2,113**	**26,070**	**12,661**	**3,757**

Table 41. Average Estimated TRM Savings (Participant Sample vs. Participant Population)

Category	Measure	TRM Savings (Sample)			TRM Savings (Population)		
		RSOP	HTR SOP	LI	RSOP	HTR SOP	LI
Shell	Air Infiltration	1,363	1,328	613	1,242	1,303	655
	Ceiling Insulation	3,552	1,889	1,083	3,356	1,887	1,259
	Floor Insulation	NA	153	237	NA	153	237
	Solar Screen	136	166	352	147	180	374
	Wall Insulation	689	954	1,182	689	972	1,199
	Windows	813	383	440	395	346	450
HVAC	AC	2,961	1,345	2,211	2,923	1,374	1,592
	Duct Sealing	668	695	460	658	697	442
	Heat Pump	7,078	6,134	5,386	6,705	5,725	5,065
	Window AC	NA	NA	613	NA	NA	613

Regression Models:

Several different regression models were used to estimate energy impacts. For reporting purposes, we use the individual household weather normalizing models; these models provide the most in-depth analysis because they use hourly data and a separate regression for every account. The results of other models mirror those of the individual household weather normalizing models. The different models used are described below, and Appendix 1-C: Model Specifications, Details, and Results presents more detailed results.

Individual Household Weather Normalization Models. This model uses hourly weather data as an input to estimate the effect of weather on each household's energy consumption. It is an account level regression analysis for both the pre- and post-period of each account. The results allow us to compare consumption in the pre- and post-period for each account using normalized weather that removes the effect of different weather conditions between the pre- and post-periods. To estimate weather-normalized consumption, observed weather data from the ASOS stations are matched with observed consumption data to build models for each household. The ideal models (heating and cooling setpoints that produce the highest R^2) for each household are then fit to TMY3 weather data, which produces consumption estimates for the situation in which weather is the same in the pre- and post-period. Weather normalizing is an important step in the analysis because differences in weather in the pre- and post-period can confound our analysis and do not allow for a direct comparison between annual pre- and post-consumption. Results are averaged over all accounts to show savings at the program and measure levels.

Program-Level Fixed-Effect Models. Unlike the *individual household* models that are run for each participant, this model is run across all participants for each program. The model estimates the average savings of each account in that program, and includes a fixed effect, which accounts for differences between homes that do not change over time, such as home size or age. The model is estimated using observed daily weather data. Once model coefficients are obtained, the model uses daily TMY3 weather data along with household-level weather coefficients as inputs to estimate weather-normalized daily consumption.

Measure-Level Fixed-Effects Models. This model is similar to the *program-level fixed-effects* model, but it contains indicator variables for each specific measure group to estimate the savings associated with each measure group. The model is estimated using real observed weather data at the daily level. Once model coefficients are obtained, the model uses daily TMY3 weather data, household-level weather coefficients, and account measure information as an input to estimate weather-normalized daily consumption.

Individual Household Weather Normalization Demand Models. This model estimates demand impacts using the *individual household weather-normalization* models mentioned above, but it focuses only on the 20 peak hours of the year as defined by Texas TRM 6.0. Using the coefficients obtained from the *individual household weather-normalized* models mentioned above, this model uses hourly TMY3 weather data and household-level weather coefficients as inputs to estimate hourly demand for the peak periods in the summer and winter.

Findings and Energy Impacts:

This section presents evaluated savings estimates for the RSOP, HTR SOP, and LI programs. Results are shown first at the program level, and then at the program-measure level.

The tables below include savings estimates as they relate to the average TRM estimates as well as how they relate to pre-period weather-normalized annual consumption (PRENAC). These metrics give the savings estimates context.

One important note is that there are differences in the methods used to calculate savings in this analysis and the methods used to calculate savings in the TRM. The TRM is designed to estimate savings for a given measure in isolation of any others. The methods used here include instances in which measures were installed in combinations of two or more as well as in isolation of others. We examined the implications of this approach for our analysis and found that all but one of the measures from this analysis were installed in isolation for the majority of accounts; duct sealing was the exception. As shown in Table 42**Error! Reference source not found.**, the large number of measures installed in isolation of any others allows us to attribute savings to a certain measure confidently.

Table 42. Isolation of Modeled Measures by Program

	RSOP			HTR SOP			LI		
Measure	Total	Isolation	Percentage of Isolation	Total	Isolation	Percentage of Isolation	Total	Isolation	Percentage of Isolation
AC	3,579	3,555	99%	17	15	88%	10	4	40%
Air Infiltration	6,306	4,221	67%	4,445	2,867	64%	173	34	20%
Ceiling Insulation	1,778	1,421	80%	2,222	1,308	59%	300	119	40%
Duct Sealing	1,970	184	9%	775	59	8%	21	0	0%
Heat Pump	2,496	2,462	99%	659	653	99%	1,467	1,379	94%

There are also differences in the weather data used to estimate savings; however, these effects should be minimal as the TRM uses a subset of the weather stations used in this analysis. The TRM uses 5 TMY3 stations, whereas this analysis uses 61 TMY3 stations. A comparison of the TMY3 stations used by the TRM and a weighted average of the cooling degree days (CDD) and heating degree days (HDD) for the TMY3 stations used in this analysis are shown in Table 43. The climate zones that make up the bulk of the analysis (mainly climate zone 2, 3, and 4) show similar total CDD and HDD numbers between the one TMY3 station used by the TRM and the several TMY3 stations used in this analysis. To calculate the weighted average HDD and CDD, we weight the annual HDD and CDD of each station in a climate zone by the proportion of accounts that were assigned to that station.

Table 43. Comparison of TRM TMY3 Weather and Consumption Analysis TMY3 Weather

TRM Station	Station Name	Climate Zone	TRM CDD (70)	TRM HDD (56)	Stations Used in Climate Zone	Weighted Average CDD	Weighted Average HDD
723630	Amarillo International	1	993	2,773	1	1,464	2,065
722590	Dallas-Fort Worth International Airport	2	1,902	1,350	30	2,016	1,396
722430	Houston Bush Intercontinental	3	1,940	763	13	1,933	613
722510	Corpus Christi International Airport	4	2,158	415	9	2,498	309
722700	El Paso International Airport	5	1,609	1,313	0	N/A	N/A

Program-Level Findings:

Table 44, Table 45, and Table 46 show the program-level savings results. These savings are calculated by averaging savings over the *individual household weather-normalization* models within each program, for both the treatment and comparison group. The effect of the program can be seen in the line titled 'Adjusted Gross,' which shows the difference between the change in normalized annual consumption of the treatment and comparison group.

While the tables rely on the *individual household level* models, we also ran *program-level fixed-effects* models that resulted in similar savings estimates. See Appendix 1-C: Model Specifications, Details, and Results for model details and savings estimates generated by the *program-level fixed-effects* model.

As a guide to the RSOP table, participants saw an average reduction in weather-normalized consumption from the pre- to post-period of 1,401 kWh. Over a similar time period, the comparison group experienced an average reduction of 173 kWh. In the final line of the table, we adjust the treatment group savings to account for the comparison group savings and estimate that the overall impact of the RSOP was about 1,228 kWh for the average treatment group household, a 7.6 percent reduction in consumption on average. Precision can be interpreted as the amount to add or subtract to the model savings (kWh) estimate to form the 90 percent confidence interval. For example, savings from the RSOP were estimated at 1,228 kWh ±5.1 percent, making the lower and upper bounds of our estimate 1,165 kWh and 1,291 kWh. The final two columns of the table display the lower and upper bound of the estimate at 90 percent confidence.

Across the three programs, the HTR SOP resulted in the lowest savings for the average participant at around five percent, and the LI program had the highest average savings at about 16 percent.

Table 44. Program-Level Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings (kWh)	Precision at 90 percent	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Savings Lower 90%	Savings Upper 90%
Treatment	13,988	16,067	1,401	5.6%	3,182	44.0%	8.7%	1,323	1,479
Comparison	10,986	17,185	173	27.2%	-	-	1.0%	126	220
Adjusted Gross	-	16,067	1,228	5.1%	3,182	38.6%	7.6%	1,165	1,291

Table 45. Program-Level Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings (kWh)	Precision at 90%	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Savings Lower 90%	Savings Upper 90%
Treatment	6,501	13,771	797	11.0%	2,263	35.2%	5.8%	709	885
Comparison	7,430	14,167	117	42.6%	-	-	0.8%	67	166
Adjusted Gross	-	13,771	681	10.7%	2,263	30.1%	4.9%	608	753

Table 46. Program-Level Results, Low-Income

LI	n	PRENAC	Model Savings (kWh)	Precision at 90%	TRM Savings (kWh)	Savings As Percentage of TRM	Savings As Percentage of PRENAC	Savings Lower 90%	Savings Upper 90%
Treatment	1,808	11,255	2,079	9.4%	4,700	44.2%	18.5%	1,884	2,274
Comparison	1,274	13,260	285	41.6%	-	-	2.1%	166	403
Adjusted Gross	-	11,255	1,794	8.6%	4,700	38.2%	15.9%	1,639	1,949

Measure Level Findings:

Overall, the measure-level results suggest that, while each of the programs is generating considerable energy savings, the TRM may be overestimating the impact of the core measures of this analysis (AC, air infiltration, ceiling insulation, duct sealing, and heat pumps).

Table 47, Table 48, and Table 49 below exhibit measure savings for the core measures of the analysis as well as other measures where the precision of the savings estimate is less than 50 percent. When considering the results, it is important to observe the number of accounts that received the measure as well as the precision of the estimate. The model estimates are less reliable when there are few accounts or the estimate is less precise (i.e., the ± value for relative precision is a large number). Appendix 1-C: Model Specifications, Details, and Results provides a complete set of measure-level results.

Table 47. Measure-Level Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre-Program	TRM Compared to Pre-Program
AC	3,579	19,654	2,229	2,961	4.0%	75.3%	11.3%	15.1%
Air Infiltration	6,306	12,961	-62	1,363	127.1%	-4.6%	-0.5%	10.5%
Ceiling Insulation	1,778	15,977	615	3,552	19.0%	17.3%	3.9%	22.2%
Duct Sealing	1,970	15,466	383	668	31.9%	57.3%	2.5%	4.3%
Heat Pump	2,496	19,145	3,160	7,078	3.3%	44.6%	16.5%	37.0%

Table 48. Measure-Level Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre-Program	TRM Compared to Pre-Program
AC	17	13,427	2,070	1,345	49.3%	153.9%	15.4%	10.0%
Air Infiltration	4,445	13,474	179	1,328	45.7%	13.4%	1.3%	9.9%
Ceiling Insulation	2,222	14,830	617	1,889	16.0%	32.7%	4.2%	12.7%
Duct Sealing	775	16,146	471	695	34.9%	67.7%	2.9%	4.3%
Heat Pump	659	12,763	2,653	6,134	6.4%	43.2%	20.8%	48.1%

Table 49. Measure-Level Results, Low-Income

LI	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre-Program	TRM Compared to Pre-Program
AC	10	11,595	1,872	2,211	75.3%	84.7%	16.1%	19.1%
Air Infiltration	173	14,130	113	613	336.7%	18.3%	0.8%	4.3%
Ceiling Insulation	300	13,231	950	1,083	30.1%	87.7%	7.2%	8.2%
Duct Sealing	21	17,578	621	460	151.1%	135.1%	3.5%	2.6%
Heat Pump	1,467	10,681	1,868	5,386	8.4%	34.7%	17.5%	50.4%
Wall Insulation	97	13,776	1,218	1,182	38.5%	103.1%	8.8%	8.6%

Overall, measure-level results are considerably lower than the TRM across all measures. The top-performing measure with a sufficiently large number of installations is *AC*, with savings estimated at about 75 percent of the TRM estimate in the RSOP.

While HVAC measure savings were lower than the TRM estimates, all *HVAC* measures showed considerably large savings. *AC* savings were closest to TRM estimates, while *heat pump* savings estimates ranged from approximately 1,900 kWh for the LI program to about 3,200 kWh for the RSOP. While this is a large amount of kWh savings, *heat pump* savings were still less than half of the TRM estimate in every program. *Duct sealing* measures produce fewer savings than other *HVAC* measures from a kWh standpoint, but the savings estimates for *duct sealing* measures in the RSOP and HTR SOP were the closest to the TRM estimates of any measure besides *AC*.

Shell measures showed the largest differences between modeled savings and TRM savings estimates. *Ceiling insulation* measure savings estimates were just 17 percent and 33 percent of the TRM estimates in RSOP and HTR SOP, respectively. The measure with the largest deviation from the TRM was *air infiltration*. In the RSOP and LI program, the air infiltration measure savings estimates were not significantly different than zero kWh, and the HTR SOP showed minimal savings at 13 percent of the TRM estimate. This low savings estimate for *air infiltration* is not the result of instability because there are few cases with *air infiltration* measures or because there are outliers skewing results. In fact, there were more *air infiltration* measures in the RSOP than any other measure (6,306). Additionally, about 65 percent of installed *air infiltration* measures were installed in isolation.

Wall insulation was not a focus of our analysis due to having a small number of installations; however, it showed strong savings in the LI program relative to the TRM at a statistically significant level of precision. We did not have a large number of *wall insulation* measures in the RSOP and HTR SOP.

Detailed Measure-Level Findings:

To disaggregate the results further, we divided the core measures of this analysis by their attributes. Table 50, Table 51, Table 52, and Table 53 show the measure categories and results by category for RSOP and HTR SOP. The LI program did not have a sufficient number of observations with measure details to be included in this part of the analysis. Many of the following findings are qualitative, based on a small number of observations with wide precision bands. We conducted these additional analyses to provide context to the overall results and to guide action plans for how to respond to the findings of this analysis.

Where ceiling insulation had a sufficient number of accounts in RSOP (R0, R0-R4, R5-R8), results were somewhat counterintuitive because higher starting R-values were associated with slightly higher savings. The difference in savings between R0-R4 and R5-R8 was relatively small at about 10 percent. In contrast, the difference in TRM estimates between the two groups was quite large, with the R0-R4 TRM estimate (4,001 kWh) being more than double the R5-R8 estimate (1,741 kWh).

Where *ceiling insulation* had a sufficient number of accounts in HTR SOP (all but R-15 to R-22), results were somewhat more intuitive, with the exception being R0 starting R-values, which were associated with lower savings estimates than similar starting R-values. Starting with R0-R4, savings decreased as starting R-value rose. Unlike the RSOP program, the trend between the R0-R4 group and the R5-R8 group mirrored the TRM trend. Model savings estimates for R0-R4 were approximately 50 percent higher than R5-R8 estimates, while TRM savings estimates for R0-R4 were approximately 59 percent higher than R5-R8 estimates.

For both the RSOP and the HTR SOP, all *ceiling insulation* segments continued to come in well below TRM estimates with the exception of HTR SOP R-15 to R-22 starting R-value projects. However, this savings estimate is based on relatively few projects (33).

Table 50. Detailed Measure-Level Results, Ceiling Insulation

Ceiling Insulation	Quartile/ Distribution	n	PRENAC	Model Savings	TRM Savings	Precision at 90%	Model as percentage of TRM	Model as percentage of PRENAC	TRM as percentage of PRENAC
RSOP	R0	420	14,594	397	3,906	58.3%	10.2%	2.7%	26.8%
	R0-R4	1,028	16,177	669	4,001	22.5%	16.7%	4.1%	24.7%
	R5-R8	286	16,894	733	1,741	38.0%	42.1%	4.3%	10.3%
	R9-R14	31	19,847	865	1,720	97.1%	50.3%	4.4%	8.7%
	R-15-R22	13	15,408	195	758	671.8%	25.8%	1.3%	4.9%
	Total	**1,778**	**15,977**	**615**	**3,552**	**19.0%**	**17.3%**	**3.9%**	**22.2%**
HTR SOP	R0	160	15,861	283	3,894	119.2%	7.3%	1.8%	24.5%
	R0-R4	798	14,583	791	2,318	19.6%	34.1%	5.4%	15.9%
	R5-R8	1,055	14,952	527	1,459	26.1%	36.1%	3.5%	9.8%
	R9-R14	176	13,430	160	828	201.1%	19.3%	1.2%	6.2%
	R-15-R22	33	19,358	1,240	1,175	59.6%	105.6%	6.4%	6.1%
	Total	**2,222**	**14,830**	**617**	**1,889**	**16.0%**	**32.7%**	**4.2%**	**12.7%**

RSOP *air infiltration* measures showed results that were not significantly different than 0 when broken down by the recorded CFM reduction percentage. HTR SOP *air infiltration* savings were lower for the lowest quartile of CFM reduction; however, they were relatively consistent across other quartiles.

Table 51. Detailed Measure Level Results, Air Infiltration

Air Infiltration	Quartile/ Distribution	n	PRENAC	Model Savings	TRM Savings	Precision at 90%	Model as percentage of TRM	Model as percentage of PRENAC	TRM as percentage of PRENAC
RSOP	Q1: 3-29% CFM	1,580	13,715	22	764	610.4%	2.9%	0.2%	5.6%
	Q2: 29-39% CFM	1,570	12,080	-5	1,054	2724.4%	-0.4%	0.0%	8.7%
	Q3: 39-61% CFM	1,575	14,032	-44	1,530	299.4%	-2.9%	-0.3%	10.9%
	Q4: 61-96% CFM	1,576	12,015	-183	2,108	68.8%	-8.7%	-1.5%	17.5%
	Total	**6,306**	**12,961**	**-62**	**1,363**	**127.1%**	**-4.6%**	**-0.5%**	**10.5%**
HTR SOP	Q1: 0-29% CFM	1,113	13,077	43	753	329.2%	5.7%	0.3%	5.8%
	Q2: 20-38% CFM	1,106	12,556	288	1,010	47.2%	28.5%	2.3%	8.0%
	Q3: 39-51% CFM	1,109	14,018	185	1,393	74.5%	13.3%	1.3%	9.9%
	Q4: 52-87% CFM	1,110	14,264	194	2,163	69.8%	9.0%	1.4%	15.2%
	Total	**4,445**	**13,474**	**179**	**1,328**	**45.7%**	**13.4%**	**1.3%**	**9.9%**

*Note: Total *n* may not match the sum of measures due to not having measure attributes for certain projects.

Duct sealing was segmented by the same metric as *air infiltration* and showed lower savings at the extremes of CFM reduction and higher savings for reductions in the 75-87 percent segments.

HTR SOP *duct sealing* performed somewhat similarly across quartiles, with the lower savings being the middle two quartiles of percent CFM reduction and the highest and lowest quartiles of CFM reduction being associated with higher savings, the opposite of the pattern shown by RSOP.

Table 52. Detailed Measure-Level Results, Duct Sealing

Duct Sealing	Quartile/ Distribution	n	PRENAC	Model Savings	TRM Savings	Precision at 90%	Model as percentage of TRM	Model as percentage of PRENAC	TRM as percentage of PRENAC
RSOP	Q1: 17-75% CFM	492	18,237	307	667	71.9%	46.0%	1.7%	3.7%
	Q2: 75-79% CFM	493	17,285	599	733	36.8%	81.7%	3.5%	4.2%
	Q3: 79-87% CFM	492	14,933	471	668	46.9%	70.5%	3.2%	4.5%
	Q4: 87-98% CFM	493	11,413	172	604	125.7%	28.5%	1.5%	5.3%
	Total	**1,970**	**15,466**	**383**	**668**	**31.9%**	**57.3%**	**2.5%**	**4.3%**
HTR SOP	Q1: 35-75% CFM	193	17,675	608	672	50.9%	90.5%	3.4%	3.8%
	Q2: 75-80% CFM	194	16,037	253	718	121.9%	35.3%	1.6%	4.5%
	Q3: 80-86% CFM	194	15,472	433	653	71.4%	66.3%	2.8%	4.2%
	Q4: 87-98% CFM	194	15,407	589	739	52.5%	79.7%	3.8%	4.8%
	Total	**775**	**16,146**	**471**	**695**	**34.9%**	**67.7%**	**2.9%**	**4.3%**

AC and *heat pumps* were segmented by seasonal energy efficiency ratio (SEER) value, with the highest savings for the segment that received SEER values of 18 or higher. *AC* results follow a more linear increase in savings with increases in SEER value, while *heat pump* savings for SEER values below 18 are relatively similar in the RSOP.

Similar segmenting was done to the HTR SOP; however, there were not enough AC units to include them as a measure group. *Heat pumps* only had sufficient data for projects where SEER value was less than 16 or exactly 15, and SEER values that were less than 16 were associated with higher savings. Still, the few accounts with a SEER value over 18 were associated with the highest savings.

Table 53. Detailed Measure-Level Results, AC and Heat Pump

AC/Heat Pump	Quartile/ Distribution	n	PRENAC	Model Savings	TRM Savings	Precision at 90%	Model as percentage of TRM	Model as percentage of PRENAC	TRM as percentage of PRENAC
AC RSOP	SEER <16	44	16,399	1,190	1,092	59.2%	109.0%	7.3%	6.7%
	SEER 16	2,169	18,907	2,038	2,413	5.4%	84.5%	10.8%	12.8%
	SEER 17	397	19,778	1,884	3,217	12.6%	58.6%	9.5%	16.3%
	SEER 18+	969	21,424	2,845	4,166	5.5%	68.3%	13.3%	19.4%
	Total	**3,579**	**19,654**	**2,229**	**2,961**	**4.0%**	**75.3%**	**11.3%**	**15.1%**
	SEER <16	436	18,275	3,318	7,618	6.9%	43.6%	18.2%	41.7%
	SEER 16	1,506	17,398	2,907	6,588	4.4%	44.1%	16.7%	37.9%

AC/Heat Pump	Quartile/ Distribution	n	PRENAC	Model Savings	TRM Savings	Precision at 90%	Model as percentage of TRM	Model as percentage of PRENAC	TRM as percentage of PRENAC
Heat Pump RSOP	SEER 17	121	23,164	3,374	6,885	12.6%	49.0%	14.6%	29.7%
	SEER 18+	421	25,222	3,936	8,388	5.9%	46.9%	15.6%	33.3%
	Total	**2,496**	**19,145**	**3,160**	**7,078**	**3.3%**	**44.6%**	**16.5%**	**37.0%**
Heat Pump HTR SOP	SEER <16	391	13,811	2,912	6,104	7.5%	47.7%	21.1%	44.2%
	SEER 16	263	11,082	2,229	6,229	11.9%	35.8%	20.1%	56.2%
	SEER 18+	5	19,285	4,257	3,446	44.2%	123.5%	22.1%	17.9%
	Total	**659**	**12,763**	**2,653**	**6,134**	**6.4%**	**43.2%**	**20.8%**	**48.1%**

*Note: Total *n* may not match the sum of measures due to not having measure attributes for certain projects.

Other Segmented Results:

Multifamily Findings:

An area of interest that arose following the initial analysis was the savings experienced by multifamily participants versus single-family participants. We modeled the measure-level analysis after segmenting the data into multifamily accounts and single-family home accounts. An account was assigned to the multifamily dataset or the single-family data set based on their address. String values indicating multifamily or apartment locations, such as apartment numbers, were identified in an automated fashion and subsequently reviewed for accuracy. Data was not separated by program for this portion of the analysis in order to maximize the number of each measure. Table 54 and Table 55show the measure level results for multifamily and single-family accounts.

Table 54. Measure-Level Results, Multifamily

Multifamily	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	11	11,452	-122	2,195	988.7%	-5.6%	-1.1%	19.2%
Air Infiltration	7,203	10,962	-49	1,384	132.4%	-3.5%	-0.4%	12.6%
Ceiling Insulation	999	10,997	501	1,826	26.2%	27.5%	4.6%	16.6%
Duct Sealing	674	9,785	113	497	141.5%	22.6%	1.2%	5.1%
Heat Pump	2,782	10,794	2,004	5,701	4.4%	35.2%	18.6%	52.8%

Table 55. Measure Level Results, Single-Family

Single-Family	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	3,594	19,627	2,284	2,953	4.0%	77.3%	11.6%	15.0%
Air Infiltration	3,695	17,475	112	1,239	107.1%	9.0%	0.6%	7.1%
Ceiling Insulation	3,268	16,437	728	2,724	13.2%	26.7%	4.4%	16.6%
Duct Sealing	2,085	17,573	441	731	34.5%	60.4%	2.5%	4.2%
Heat Pump	1,829	22,820	3,773	7,492	3.2%	50.4%	16.5%	32.8%

The tables above indicate that the single-family savings estimates were greater for every core measure category. It is important to note that measures with precision greater than 100 percent are not exhibiting savings significantly different than zero kWh.

While the point estimate for *air infiltration* is higher for single-family participants, it is not significantly different than zero kWh. *Duct sealing* and *heat pumps* performed more strongly for single-family homes, both on an absolute savings level as well as when compared to the TRM. *Ceiling insulation* was the only measure that produced similar results across the two segments. *AC* is the only measure where we cannot compare single-family and multifamily results because of the low number of cases in the multifamily segment.

Heating Type Findings:

We examined the heating type of accounts that received *air infiltration*, *ceiling insulation*, and *duct sealing* measures. The heating type was available for most treatment group accounts; however, it was not available for many comparison group accounts. In order to keep comparisons consistent, only comparison group accounts where the heating type was known were used. This approach may have led to slightly higher savings estimates, as the comparison group savings in these models were not significantly different than zero kWh for any segment. By contrast, comparison group savings for the RSOP, HTR SOP, and LI programs were about 160, 120, and 300 kWh on average, respectively. Table 56, Table 57, and Table 58 show the results by heating type.

Table 56. Measure Level Results, Electric Resistance Heat in Pre- and Post-Period

Electric Resistance	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Air Infiltration	9,988	12,967	204	1,386	49.4%	14.7%	1.6%	10.7%
Ceiling Insulation	2,611	15,646	830	3,233	13.0%	25.7%	5.3%	20.7%
Duct Sealing	2,492	15,841	431	700	22.4%	61.6%	2.7%	4.4%

Table 57. Measure Level Results, Gas Heat in Pre- and Post-Period

Gas	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	5	14,415	2,595	2,355	67.4%	110.2%	18.0%	16.3%
Air Infiltration	432	13,354	124	462	228.9%	26.8%	0.9%	3.5%
Ceiling Insulation	1,052	13,081	526	1,074	49.7%	48.9%	4.0%	8.2%
Duct Sealing	196	13,837	404	436	102.6%	92.8%	2.9%	3.1%
Wall Insulation	55	12,709	1,349	927	41.3%	145.6%	10.6%	7.3%

Table 58. Measure-Level Results, Heat Pump in Pre- and Post-Period

Heat Pump	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Air Infiltration	426	17,533	240	1,105	155.7%	21.7%	1.4%	6.3%
Ceiling Insulation	416	18,195	1,012	2,225	37.6%	45.5%	5.6%	12.2%
Duct Sealing	70	15,228	183	489	366.4%	37.4%	1.2%	3.2%

In the above tables, *ceiling insulation* savings show variation between heating types, while other measures of interest are relatively constant in terms of absolute kWh savings. In relation to the TRM, of the measures of interest, *duct sealing* measures for accounts with gas heat are closest to the TRM estimate at 93 percent.

Replacement of Heat Pump Findings:

We examined how savings are affected by the type of heating system that the heat pump is replacing. In Table 59, we present data on heat pumps replacing electric resistance heat, followed by data on heat pumps replacing heat pumps.

Heat pumps replacing heat pumps make up less of the measures and have a similar level of savings to heat pumps replacing electric resistance heat in terms of kWh; however, they are far closer to the TRM savings estimate.

Table 59. Heat Pump Results by Existing Heating Type

Existing Heating Type	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Electric Resistance	3,151	15,598	3,275	7,773	5.6%	42.1%	21.0%	49.8%
Heat Pump	831	23,129	3,599	3,755	14.0%	95.8%	15.6%	16.2%

We also ran models comparing the type of replacement for the heat pump (early retirement or burnout). Across all programs, savings were similar between the two replacement options. Savings for each program are shown in Table 60, Table 61, and Table 62.

Table 60. Heat Pump Replacement Type Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Early Retirement	2,293	18,931	3,176	7,257	3.4%	43.8%	16.8%	38.3%
Burnout	189	21,715	3,168	5,094	10.8%	62.2%	14.6%	23.5%

Table 61. Heat Pump Replacement Type Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Early Retirement	651	12,690	2,655	6,175	6.5%	43.0%	20.9%	48.7%
Burnout	8	18,722	2,500	2,781	59.5%	89.9%	13.4%	14.9%

Table 62. Heat Pump Replacement Type Results, Low-Income

Low Income	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Early Retirement	594	11,309	1,932	5,943	11.0%	32.5%	17.1%	52.5%
Burnout	96	11,844	1,774	5,607	25.6%	31.6%	15.0%	47.3%

Replacement of AC Findings:

We compared the savings of AC units based on the type of replacement, which is shown in Table 63. Early retirement was associated with higher absolute savings, but the estimated savings for early retirement replacements was further from the TRM savings estimate. Only the RSOP had a sufficient number of accounts to warrant further analysis of AC replacement.

Table 63. Air Conditioning Replacement Type Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
Early Retirement	3,116	19,897	2,303	3,122	4.1%	73.8%	11.6%	15.7%
Burnout	463	18,019	1,732	1,878	12.8%	92.2%	9.6%	10.4%

Peak Demand Findings:

Peak demand savings were estimated using our *individual household weather-normalizing* models for the top 20 hours for the summer and winter periods in the pre- and post-period. The TRM defines the top 20 hours. We then look at the mean difference between the pre- and post-period demand for both the summer and winter periods. For more details on the calculation, see

Appendix D. Results are shown below, first at the program level (Table 64and Table 65) and then at the measure level (Table 66, Table 67, and Table 68).

Table 64. Program-Level Peak Demand Results

Program	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
RSOP	Treatment	13,988	4.05	0.47	1.92	24.3%	11.5%
	Comparison	10,986	4.51	0.15	-	-	3.2%
	Adjusted Gross		4.05	0.32	1.92	16.7%	7.9%
HTR SOP	Treatment	6,501	3.00	0.16	1.62	9.8%	5.3%
	Comparison	7,430	3.03	0.04	-	-	1.2%
	Adjusted Gross		3.00	0.12	1.62	7.5%	4.1%
LI	Treatment	1,808	2.62	0.49	2.77	17.7%	18.7%
	Comparison	1,274	2.81	0.16	-	-	5.8%
	Adjusted Gross		2.62	0.33	2.77	11.8%	12.5%
Program	Group	n	Winter				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
RSOP	Treatment	13,988	3.98	0.83	1.92	43.2%	20.9%
	Comparison	10,986	4.00	0.39	-	-	9.9%
	Adjusted Gross		3.98	0.44	1.92	22.7%	11.0%
HTR SOP	Treatment	6,501	3.85	0.72	1.62	44.3%	18.6%
	Comparison	7,430	4.08	0.37	-	-	9.1%
	Adjusted Gross		3.85	0.34	1.62	21.3%	9.0%
LI	Treatment	1,808	3.12	0.94	2.77	33.8%	30.0%
	Comparison	1,274	3.63	0.29	-	-	7.9%
	Adjusted Gross		3.12	0.65	2.77	23.5%	20.8%

At the program level, the winter peak savings are higher than summer for each program; however, the average savings provided come in far lower than the TRM estimates. The savings as a percentage of pre-program are fairly consistent with the program-level consumption analysis results but are a bit higher for each program. These are at 11, 9, and 21 percent for the RSOP, HTR SOP, and LI programs for winter peak reduction, respectively.

Compared to the 2014 consumption analysis, the savings for the RSOP were very similar, as that analysis found summer and winter peak reductions of 8 and 10 percent for the RSOP, and here we see 8 and 11 percent. The HTR SOP demand reduction estimates are lower than the previous analysis. The 2014 analysis noted 8 and 12 percent for summer and winter peak reductions while our models estimate a reduction of 4 and 9 percent.

As a supplement to the above analysis, we segmented participants by whether their winter or summer peak savings were higher rather than including all participants in both summer and winter results, as was done above. Savings estimates increased, as shown by the table below. This increase is to be expected since the higher savings are kept within each group, and the lower savings are effectively removed. By breaking out the data in this way, we can see how those accounts that benefit more from either the summer peak or winter peak compare to the comparison group. With this separation in place, winter peak savings were still larger than summer peak savings. While there was some improvement in the alignment of TRM and modeled savings, the TRM still overestimates kW reductions.

Table 65. Program-Level Peak Demand Results, Participants Segmented by Summer and Winter

Program	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
RSOP	Treatment	5,772	4.83	1.00	1.72	58.3%	20.7%
	Comparison	10,986	4.51	0.15	-	-	3.2%
	Adjusted Gross		4.83	0.86	1.72	49.8%	17.7%
HTR SOP	Treatment	2,229	3.19	0.55	1.50	36.7%	17.2%
	Comparison	7,430	3.03	0.04	-	-	1.2%
	Adjusted Gross		3.19	0.51	1.50	34.3%	16.1%
LI	Treatment	690	3.01	0.87	2.54	34.4%	29.1%
	Comparison	1,274	2.81	0.16	-	-	5.8%
	Adjusted Gross		3.01	0.71	2.54	28.0%	23.6%
Program	**Group**	**n**	**Winter**				
			Peak Pre	**Model Savings (kW)**	**TRM Savings**	**Model as percentage of TRM**	**Savings as percentage of Pre**
RSOP	Treatment	8,216	4.83	1.53	2.07	74.2%	31.8%
	Comparison	10,986	4.00	0.39	-	-	9.9%
	Adjusted Gross		4.83	1.14	2.07	55.1%	23.6%
HTR SOP	Treatment	4,272	4.38	1.25	1.68	74.5%	28.7%
	Comparison	7,430	4.08	0.37	-	-	9.1%
	Adjusted Gross		4.38	0.88	1.68	52.4%	20.2%
LI	Treatment	1,118	3.66	1.52	2.91	52.4%	41.6%
	Comparison	1,274	3.63	0.29	-	-	7.9%
	Adjusted Gross		3.66	1.24	2.91	42.5%	33.8%

The peak demand reduction at the measure level follows a similar pattern in that the winter peak savings were higher for all measures except for *AC*. Focusing on the savings as a percentage of the TRM estimate column, we see that the peak demand reductions were quite similar to the measure-level consumption analysis estimates in relation to how they compare to the TRM estimate. The exception is *duct sealing*, which was higher than the TRM estimate. Similar to the analysis discussed thus far, all peak demand savings estimates are considerably lower than the TRM estimate, with the exception of *duct sealing*.

Table 66. Measure-Level Peak Demand Results, Residential Standard Offer Program

RSOP	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	3,579	6.60	1.22	1.57	77.5%	18.4%
	Comparison	10,986	4.51	0.14	-	-	3.1%
	Adjusted Gross		6.60	1.08	1.57	68.7%	16.3%

RSOP	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
Air Infiltration	Treatment	6,306	2.70	0.02	1.22	1.9%	0.9%
	Comparison	10,986	4.51	0.14	-	-	3.1%
	Adjusted Gross		2.70	-0.11	1.22	-9.4%	-4.3%
Ceiling Insulation	Treatment	1,778	3.80	0.30	2.43	12.2%	7.8%
	Comparison	10,986	4.51	0.14	-	-	3.1%
	Adjusted Gross		3.80	0.16	2.43	6.5%	4.2%
Duct Sealing	Treatment	1,970	3.40	0.18	0.23	79.2%	5.3%
	Comparison	10,986	4.51	0.14	-	-	3.1%
	Adjusted Gross		3.40	0.04	0.23	18.3%	1.2%
Heat Pump	Treatment	2,496	4.07	0.62	3.54	17.6%	15.3%
	Comparison	10,986	4.51	0.14	-	-	3.1%
	Adjusted Gross		4.07	0.49	3.54	13.7%	11.9%

RSOP	Group	n	Winter				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	3,579	2.25	0.40	1.57	25.4%	17.7%
	Comparison	10,986	4.00	0.39	-	-	9.7%
	Adjusted Gross		2.25	0.01	1.57	0.6%	0.5%
Air Infiltration	Treatment	6,306	3.92	0.38	1.22	31.3%	9.7%
	Comparison	10,986	4.00	0.39	-	-	9.7%
	Adjusted Gross		3.92	-0.01	1.22	-0.6%	-0.2%
Ceiling Insulation	Treatment	1,778	4.49	0.83	2.43	34.1%	18.4%
	Comparison	10,986	4.00	0.39	-	-	9.7%
	Adjusted Gross		4.49	0.44	2.43	18.1%	9.8%
Duct Sealing	Treatment	1,970	3.89	0.78	0.23	343.9%	20.0%
	Comparison	10,986	4.00	0.39	-	-	9.7%
	Adjusted Gross		3.89	0.39	0.23	172.6%	10.0%
Heat Pump	Treatment	2,496	6.51	2.29	3.54	64.8%	35.2%
	Comparison	10,986	4.00	0.39	-	-	9.7%
	Adjusted Gross		6.51	1.91	3.54	53.8%	29.3%

Savings estimates for the HTR SOP were quite similar to the RSOP estimates among measures, with slightly higher savings estimates in relation to the TRM for *air infiltration* and *ceiling insulation*. *Duct sealing* again had a model savings estimate that was far greater than the TRM estimate. *Heat pump* savings estimates were slightly lower for the HTR SOP program than they were for RSOP.

Table 67. Measure-Level Peak Demand Results, Hard-To-Reach Standard Offer Program

HTR SOP	Group	n	Summer Peak Pre	Summer Model Savings (kW)	Summer TRM Savings	Summer Model as percentage of TRM	Summer Savings as percentage of Pre
AC	Treatment	17	4.11	0.60	0.75	79.7%	14.6%
	Comparison	7,430	3.03	0.04	-	-	1.4%
	Adjusted Gross		4.11	0.56	0.75	74.2%	13.6%
Air Infiltration	Treatment	4,445	2.71	0.04	1.20	3.3%	1.5%
	Comparison	7,430	3.03	0.04	-	-	1.4%
	Adjusted Gross		2.71	0.00	1.20	-0.1%	0.0%
Ceiling Insulation	Treatment	2,222	3.83	0.25	1.25	20.1%	6.6%
	Comparison	7,430	3.03	0.04	-	-	1.4%
	Adjusted Gross		3.83	0.21	1.25	16.8%	5.5%
Duct Sealing	Treatment	775	3.50	0.10	0.24	39.9%	2.8%
	Comparison	7,430	3.03	0.04	-	-	1.4%
	Adjusted Gross		3.50	0.06	0.24	22.9%	1.6%
Heat Pump	Treatment	659	2.44	0.36	3.37	10.7%	14.8%
	Comparison	7,430	3.03	0.04	-	-	1.4%
	Adjusted Gross		2.44	0.32	3.37	9.5%	13.1%

HTR SOP	Group	n	Winter Peak Pre	Winter Model Savings (kW)	Winter TRM Savings	Winter Model as percentage of TRM	Winter Savings as percentage of Pre
AC	Treatment	17	1.30	0.14	0.75	18.3%	10.6%
	Comparison	7,430	4.08	0.37	-	-	9.0%
	Adjusted Gross		1.30	-0.23	0.75	-30.5%	-17.6%
Air Infiltration	Treatment	4,445	3.88	0.43	1.20	35.9%	11.1%
	Comparison	7,430	4.08	0.37	-	-	9.0%
	Adjusted Gross		3.88	0.06	1.20	5.3%	1.6%
Ceiling Insulation	Treatment	2,222	3.99	0.71	1.25	57.0%	17.8%
	Comparison	7,430	4.08	0.37	-	-	9.0%
	Adjusted Gross		3.99	0.35	1.25	27.7%	8.7%
Duct Sealing	Treatment	775	4.29	0.97	0.24	401.4%	22.7%
	Comparison	7,430	4.08	0.37	-	-	9.0%
	Adjusted Gross		4.29	0.61	0.24	250.4%	14.1%
Heat Pump	Treatment	659	4.08	1.58	3.37	46.9%	38.8%
	Comparison	7,430	4.08	0.37	-	-	9.0%
	Adjusted Gross		4.08	1.22	3.37	36.1%	29.8%

In the LI program, savings estimates were slightly higher than savings estimates from the RSOP and HTR SOP for *air infiltration* and *ceiling insulation* but were lower for heat pumps. *AC* and *duct sealing* had a low number of observations in this program.

Table 68. Measure-Level Peak Demand Results, Low-Income

LI	Group	n	Summer Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	10	3.66	0.81	1.36	59.8%	22.2%
	Comparison	1,274	2.81	0.17	-	-	6.2%
	Adjusted Gross		3.66	0.64	1.36	47.1%	17.5%
Air Infiltration	Treatment	173	3.83	0.20	0.52	37.8%	5.1%
	Comparison	1,274	2.81	0.17	-	-	6.2%
	Adjusted Gross		3.83	0.02	0.52	4.5%	0.6%
Ceiling Insulation	Treatment	300	3.51	0.37	0.79	47.0%	10.6%
	Comparison	1,274	2.81	0.17	-	-	6.2%
	Adjusted Gross		3.51	0.20	0.79	25.0%	5.6%
Duct Sealing	Treatment	21	4.45	0.53	0.27	199.0%	11.9%
	Comparison	1,274	2.81	0.17	-	-	6.2%
	Adjusted Gross		4.45	0.36	0.27	133.7%	8.0%
Heat Pump	Treatment	1,467	2.35	0.50	3.11	16.0%	21.2%
	Comparison	1,274	2.81	0.17	-	-	6.2%
	Adjusted Gross		2.35	0.32	3.11	10.4%	13.8%

LI	Group	n	Winter Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	10	1.58	0.22	1.36	16.0%	13.8%
	Comparison	1,274	3.63	0.26	-	-	7.1%
	Adjusted Gross		1.58	-0.04	1.36	-3.0%	-2.6%
Air Infiltration	Treatment	173	3.22	0.42	0.52	81.0%	13.2%
	Comparison	1,274	3.63	0.26	-	-	7.1%
	Adjusted Gross		3.22	0.17	0.52	31.7%	5.1%
Ceiling Insulation	Treatment	300	3.01	0.55	0.79	70.2%	18.4%
	Comparison	1,274	3.63	0.26	-	-	7.1%
	Adjusted Gross		3.01	0.30	0.79	37.5%	9.8%
Duct Sealing	Treatment	21	4.68	0.92	0.27	344.7%	19.6%
	Comparison	1,274	3.63	0.26	-	-	7.1%
	Adjusted Gross		4.68	0.66	0.27	247.8%	14.1%
Heat Pump	Treatment	1,467	3.20	1.00	3.11	32.1%	31.1%
	Comparison	1,274	3.63	0.26	-	-	7.1%
	Adjusted Gross		3.20	0.74	3.11	23.8%	23.1%

Similar to the analysis that was conducted at the program level, we segmented accounts into summer or winter peak groups based on which time period resulted in a larger demand reduction. The only exception to this method of segmentation was *AC* measures, which were only included in summer peak results. Additionally, rather than comparing the treatment group reduction to the entire comparison group for that program, only accounts in the same program that were scheduled to receive the same measure were used. Table 69, Table 70, and Table 71 display the results for each program.

In the RSOP, winter peak continued to see larger savings than summer peak savings estimates. Savings estimates relative to the TRM were slightly higher than they were in the consumption analysis as well as the above analysis. While *air infiltration* and *ceiling insulation* savings estimates were closer to TRM estimates, even with just the winter peak accounts, they each reached only about 40 percent of the TRM estimate.

Table 69. Segmented Measure-Level Peak Demand Results, Residential Standard Offer Program

RSOP	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	3,579	6.61	1.22	1.57	77.5%	18.4%
	Comparison	3,288	6.82	0.25	-	-	3.6%
	Adjusted Gross		6.61	0.97	1.57	61.8%	14.7%
Air Infiltration	Treatment	2,127	2.72	0.34	1.25	27.3%	12.6%
	Comparison	3,451	3.10	0.05	-	-	1.7%
	Adjusted Gross		2.72	0.29	1.25	23.2%	10.7%
Ceiling Insulation	Treatment	608	4.10	0.57	2.39	23.8%	13.9%
	Comparison	1,514	3.62	0.01	-	-	0.3%
	Adjusted Gross		4.10	0.56	2.39	23.4%	13.7%
Duct Sealing	Treatment	527	3.52	0.06	0.22	29.3%	1.8%
	Comparison	2,246	3.42	0.04	-	-	1.1%
	Adjusted Gross		3.52	0.03	0.22	12.1%	0.7%
Heat Pump	Treatment	491	4.24	0.94	2.92	32.2%	22.2%
	Comparison	2,811	4.02	0.17	-	-	4.3%
	Adjusted Gross		4.24	0.77	2.92	26.3%	18.1%
RSOP	Group	n	Winter				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
Air Infiltration	Treatment	4,179	4.27	1.05	1.20	87.4%	24.6%
	Comparison	3,451	3.90	0.57	-	-	14.6%
	Adjusted Gross		4.27	0.48	1.20	40.0%	11.3%
Ceiling Insulation	Treatment	1,170	5.13	1.36	2.45	55.6%	26.5%
	Comparison	1,514	3.79	0.40	-	-	10.6%
	Adjusted Gross		5.13	0.96	2.45	39.2%	18.7%
Duct Sealing	Treatment	1,443	4.15	1.09	0.23	472.7%	26.2%
	Comparison	2,246	3.98	0.68	-	-	17.1%
	Adjusted Gross		4.15	0.41	0.23	177.2%	9.8%
Heat Pump	Treatment	2,005	6.95	2.89	3.69	78.2%	41.5%
	Comparison	2,811	6.31	0.46	-	-	7.4%
	Adjusted Gross		6.95	2.42	3.69	65.6%	34.9%

HTR SOP savings estimates were again similar to the RSOP estimates among measures. Winter peak continued to reflect higher savings estimates within each measure.

Table 70. Segmented Measure-Level Peak Demand Results, Hard-To-Reach Standard Offer Program

HTR SOP	Group	n	Summer				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
AC	Treatment	17	4.11	0.61	0.75	81.0%	14.8%
	Comparison	16	3.74	0.12	-	-	3.2%
	Adjusted Gross		4.11	0.49	0.75	65.2%	11.9%
Air Infiltration	Treatment	1,474	2.82	0.37	1.17	31.5%	13.1%
	Comparison	4,810	2.75	0.06	-	-	2.0%
	Adjusted Gross		2.82	0.31	1.17	26.8%	11.2%
Ceiling Insulation	Treatment	828	4.21	0.58	1.21	47.5%	13.7%
	Comparison	2,506	3.80	0.09	-	-	2.3%
	Adjusted Gross		4.21	0.49	1.21	40.2%	11.6%
Duct Sealing	Treatment	160	3.49	0.13	0.25	53.7%	3.9%
	Comparison	697	3.75	0.19	-	-	5.1%
	Adjusted Gross		3.49	-0.06	0.25	-22.2%	-1.6%
Heat Pump	Treatment	194	2.20	0.68	2.86	23.8%	30.9%
	Comparison	1,076	2.28	0.11	-	-	4.7%
	Adjusted Gross		2.20	0.57	2.86	20.0%	26.1%

HTR SOP	Group	n	Winter				
			Peak Pre	Model Savings (kW)	TRM Savings	Model as percentage of TRM	Savings as percentage of Pre
Air Infiltration	Treatment	2,971	4.24	0.85	1.21	70.2%	20.0%
	Comparison	4,810	3.99	0.44	-	-	10.9%
	Adjusted Gross		4.24	0.41	1.21	34.1%	9.7%
Ceiling Insulation	Treatment	1,394	4.85	1.09	1.27	85.7%	22.5%
	Comparison	2,506	4.50	0.36	-	-	7.9%
	Adjusted Gross		4.85	0.73	1.27	57.6%	15.1%
Duct Sealing	Treatment	615	4.51	1.24	0.24	515.0%	27.4%
	Comparison	697	4.55	0.74	-	-	16.4%
	Adjusted Gross		4.51	0.49	0.24	205.2%	10.9%
Heat Pump	Treatment	465	4.89	2.27	3.59	63.2%	46.4%
	Comparison	1,076	3.51	0.42	-	-	12.0%
	Adjusted Gross		4.89	1.85	3.59	51.5%	37.8%

The LI program had some interesting results in this portion of the analysis as *air infiltration* exceeded the TRM savings estimate for winter peak, along with *duct sealing*. *Ceiling insulation* had savings that were higher than they were in the other two programs at 70 percent of the TRM estimate. *Heat pump* savings were lower than in the RSOP and HTR SOP at 37 percent.

Table 71. Segmented Measure-Level Peak Demand Results, Low-Income

LI	Group	n	Summer Peak Pre	Summer Model Savings (kW)	Summer TRM Savings	Summer Model as percentage of TRM	Summer Savings as percentage of Pre
AC	Treatment	10	3.66	0.88	1.36	65.0%	24.2%
	Comparison	7	5.29	0.36	-	-	6.8%
	Adjusted Gross		3.66	0.52	1.36	38.5%	14.3%
Air Infiltration	Treatment	81	3.96	0.18	0.52	34.0%	4.4%
	Comparison	338	2.46	0.12	-	-	5.1%
	Adjusted Gross		3.96	0.05	0.52	10.0%	1.3%
Ceiling Insulation	Treatment	130	3.99	0.71	0.77	92.5%	17.9%
	Comparison	282	4.09	0.21	-	-	5.0%
	Adjusted Gross		3.99	0.51	0.77	65.8%	12.7%
Duct Sealing	Treatment	8	4.98	0.88	0.19	455.5%	17.6%
	Comparison	31	5.01	0.35	-	-	7.0%
	Adjusted Gross		4.98	0.52	0.19	271.9%	10.5%
Heat Pump	Treatment	518	2.65	0.88	3.00	29.4%	33.3%
	Comparison	976	2.44	0.16	-	-	6.5%
	Adjusted Gross		2.65	0.72	3.00	24.1%	27.4%

LI	Group	n	Winter Peak Pre	Winter Model Savings (kW)	Winter TRM Savings	Winter Model as percentage of TRM	Winter Savings as percentage of Pre
Air Infiltration	Treatment	92	4.47	0.79	0.53	150.1%	17.7%
	Comparison	338	3.21	0.18	-	-	5.7%
	Adjusted Gross		4.47	0.61	0.53	115.4%	13.6%
Ceiling Insulation	Treatment	170	3.84	0.80	0.80	99.8%	20.8%
	Comparison	282	3.01	0.24	-	-	7.9%
	Adjusted Gross		3.84	0.56	0.80	70.0%	14.6%
Duct Sealing	Treatment	13	5.28	0.98	0.31	313.4%	18.5%
	Comparison	31	2.72	0.30	-	-	10.9%
	Adjusted Gross		5.28	0.68	0.31	218.4%	12.9%
Heat Pump	Treatment	949	3.64	1.53	3.17	48.2%	41.9%
	Comparison	976	3.89	0.34	-	-	8.8%
	Adjusted Gross		3.64	1.18	3.17	37.4%	32.6%

APPENDIX 1-A: SUPPLEMENTAL INFORMATION ON WEATHER DATA

Introduction:

In order to weather-normalize the electricity consumption of all households involved in the consumption analysis, we needed observed weather data for the time period of 2017 through 2019 to generate model coefficients. Below we give details about the data, describe the weather stations that were used, and how missing data were handled.

Collection:

Weather data for all ASOS stations were downloaded from Iowa State University's Mesonet[23] and added to our database. The ASOS network is a collection of automated airport weather observations from around the world with 208 stations in Texas. The data contains hourly temperature readings, and we downloaded data for the time period of January 1, 2017, to January 1, 2020. In some cases, there is more than one temperature reading per hour. In these situations, we average the temperature during that hour to come to one single temperature for that hour.

Station Selection:

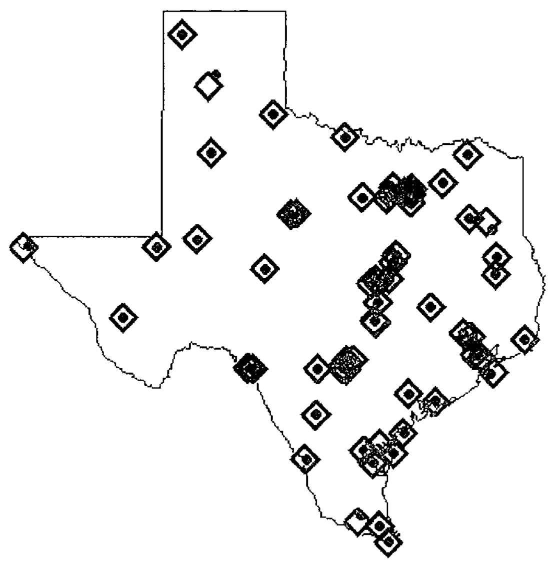
While there are 208 ASOS stations, only 59 were used. The reason for this is that each account (there are 61) would also need to be matched with a TMY3 weather station to complete the weather normalization. A majority of TMY3 and ASOS stations are co-located, and all TMY3 stations are within 20 miles of their matched ASOS stations, with 59 of the 61 within 10 miles. This analysis increased the number of available observed weather stations to 59, up from 13 in the 2014 consumption analysis, to increase the accuracy of models for each household. Additionally, while there are 208 ASOS stations, many stations' data are unsuitable for this analysis, as many have large amounts of missing data.

As mentioned above, we used the closest ASOS station to each TMY3 station. Distance between stations is measured in a straight line, often referred to as "*as the crow flies*." There are two fewer ASOS stations because station ATT (Austin) is the closest ASOS station to two different TMY3 stations (Austin Mueller Airport and Camp Mabry), and one ASOS station could not be used due to missing data. This station was VCT (Victoria Regional), and it appears to be missing several observations due to Hurricane Harvey.

[23] https://mesonet.agron.iastate.edu/.

Figure 38 displays a map of the stations, with the ASOS stations represented by the blue dots and the TMY3 stations represented by the red squares.

Figure 38. Map of Texas ASOS Weather Stations and TMY3 Weather Stations



Filling Gaps:

All of the 59 ASOS stations used for the analysis were missing some data. In order to complete the hourly weather observations needed to run hourly regression models, when data were missing, they were imputed from the nearest (in miles) weather station. Distance between stations was again measured in a straight line. When imputing data, we open our search to all 208 ASOS stations to get weather data from the closest available station. The final observed weather dataset has contributions from 107 stations.

When filling missing observations with the closest station proves insufficient to complete data for a given station, we use the second closest station to fill the missing data, and so on until as much missing data as possible are eliminated through data of nearby stations. For some stations, we go as far as a fourth station, provided that the distance is reasonable, which we generally consider being distances less than 50 miles. The stations used in the analysis are summarized below, showing the amount of data original to that station and the amount borrowed from other stations. We also show the distance between stations in miles. In the end, only 51 of the 59 stations were used in the final consumption analysis as eight of the stations were not the closest station to a single account. Overall, the distance between a borrowing and lending station was infrequently in excess of 30 miles, with only 10 of the 51 stations imputing data from a station that was beyond 30 miles. All information on the amount of data that is original to each weather station and the amount borrowed from another station can be seen in **Error! Reference source not found.**. As a guide through the table, station ABI had 99.4% complete data to start with, borrowed about 0.6% from station DYS, and had approximately 0.1% of observations approximated. When our method of borrowing data cannot fill in all missing data, we turn to approximate the missing weather data through the use of linear interpolation. The approximation is detailed following the table.

Table 72. Summary of Weather Station Data and Imputation Rates

Station	Percentage of Original	Secondary Station	Percentage	Distance from Station	Third Station	Percentage	Distance from Station	Fourth Station	Distance from Station	Percentage	Approximated Percentage
ABI	99.4%	DYS	0.6%	10	-	-	-	-	-	-	0.1%
ACT	99.0%	CNW	0.5%	9	PWG	0.3%	11	-	-	-	0.3%
ADS	95.4%	DAL	4.5%	8	-	-	-	-	-	-	0.1%
AFW	99.7%	FTW	0.1%	11	-	-	-	-	-	-	0.1%
ALI	97.5%	NOG	2.1%	11	IKG	0.3%	13	-	-	-	0.0%
ATT	97.5%	AUS	2.5%	10	-	-	-	-	-	-	0.0%
BRO	99.3%	PIL	0.2%	18	SPL	0.0%	20	HRL	26	0.2%	0.3%
CDS	99.4%	F05	0.5%	59	PVW	0.1%	84	-	-	-	0.0%
CLL	99.6%	CFD	0.4%	9	-	-	-	-	-	-	0.1%
COT	98.5%	CZT	0.9%	37	FTN	0.6%	52	-	-	-	0.0%
DAL	99.8%	ADS	0.1%	8	-	-	-	-	-	-	0.1%
DFW	99.8%	DAL	0.0%	11	-	-	-	-	-	-	0.1%
DLF	94.1%	DRT	5.5%	9	T70	0.2%	24	-	-	-	0.2%
DRT	98.0%	DLF	1.7%	9	T70	0.2%	32	-	-	-	0.2%
DWH	99.2%	IAH	0.7%	14	-	-	-	-	-	-	0.1%
DYS	95.6%	ABI	4.3%	10	-	-	-	-	-	-	0.1%
EBG	99.2%	MFE	0.7%	20	-	-	-	-	-	-	0.1%
EFD	88.3%	HOU	11.6%	8	-	-	-	-	-	-	0.1%
FTW	99.2%	NFW	0.8%	5	-	-	-	-	-	-	0.0%
GLS	99.2%	LVJ	0.6%	29	EFD	0.2%	30	-	-	-	0.1%
GRK	97.9%	HLR	0.7%	8	ILE	1.3%	9	-	-	-	0.2%
GTU	87.9%	T74	0.0%	16	EDC	11.8%	21	RYW	21	0.3%	0.0%
GVT	99.5%	F46	0.4%	23	-	-	-	-	-	-	0.1%
HDO	97.2%	CVB	2.7%	20	SKF	0.1%	36	-	-	-	0.0%
HLR	90.9%	ILE	7.7%	4	GRK	1.2%	8	-	-	-	0.2%
HOU	99.8%	EFD	0.2%	8	-	-	-	-	-	-	0.1%
HRL	98.6%	T65	0.3%	20	TXW	0.9%	20	PIL	20	0.1%	0.1%
IAH	99.8%	DWH	0.0%	14	-	-	-	-	-	-	0.1%
ILE	92.0%	HLR	6.6%	4	GRK	1.2%	9	-	-	-	0.2%
INK	95.8%	PEQ	4.1%	33	-	-	-	-	-	-	0.1%
LFK	99.2%	OCH	0.7%	24	-	-	-	-	-	-	0.1%
LRD	98.7%	APY	1.2%	42	HBV	0.1%	46	-	-	-	0.1%
MAF	99.7%	MDD	0.3%	8	-	-	-	-	-	-	0.1%
MRF	89.1%	E38	10.7%	20	PRS	0.1%	55	-	-	-	0.1%
MWL	99.7%	GDJ	0.2%	27	-	-	-	-	-	-	0.1%
NFW	95.4%	FTW	4.5%	5	-	-	-	-	-	-	0.0%
NGP	95.6%	CRP	4.3%	15	RAS	0.0%	15	TFP	16	0.0%	0.1%
NQI	98.0%	IKG	1.9%	14	RBO	0.1%	20	-	-	-	0.0%

Station	Percentage of Original	Secondary Station	Percentage	Distance from Station	Third Station	Percentage	Distance from Station	Fourth Station	Distance from Station	Percentage	Approximated Percentage
OCH	92.6%	LFK	7.3%	24	-	-	-	-	-	-	0.1%
PRX	90.3%	LBR	0.0%	23	SLR	9.6%	34	-	-	-	0.1%
PSX	97.2%	PKV	2.0%	27	BYY	0.6%	29	-	-	-	0.2%
PWG	91.1%	ACT	8.4%	11	CNW	0.3%	18	-	-	-	0.3%
RBD	98.4%	GPM	1.5%	10	-	-	-	-	-	-	0.1%
RBO	86.6%	CRP	13.3%	11	-	-	-	-	-	-	0.1%
RFI	91.3%	GGG	8.6%	19	JSO	0.1%	29	-	-	-	0.0%
RKP	97.8%	TFP	1.6%	16	RAS	0.0%	19	CRP	31	0.5%	0.1%
SJT	99.5%	SOA	0.4%	54	OZA	0.0%	60	-	-	-	0.1%
SPS	99.5%	CWC	0.4%	8	-	-	-	-	-	-	0.1%
SSF	99.4%	SKF	0.5%	7	-	-	-	-	-	-	0.0%
TPL	97.1%	ILE	2.5%	17	HLR	0.4%	18	-	-	-	0.1%
TYR	98.9%	JDD	1.0%	27	-	-	-	-	-	-	0.1%

We fill missing observations with nearby stations until there are no more nearby stations from which to impute weather data. After borrowing from up to three stations, the longest consecutive streak of missing hourly temperature readings is 14. The vast majority of missing data streaks are far less than 14 hours, with only four stations having a consecutive streak of missing hourly temperature readings greater than 7 hours. At this point, the distance to borrow from the next station becomes further than we feel accurate. To fill in the remaining gaps, we create a linear interpolation using the observations immediately prior and following the stretch of missing hourly data to estimate the temperature during each hour with missing data. Doing this for short streaks of 14 hours or less keeps the estimations reasonable, and some visual inspection of the data has shown periods of approximation to work well. To provide an example, if June 20 had a reading of 74 degrees at 3:00 p.m. and 78 degrees at 6:00 p.m. with missing data in between, our data imputation procedures would impute those hours as 75.3 and 76.6 for the missing observations at 4:00 p.m. and 5:00 p.m. The data are always filled in a linear manner, representing a gradual increase or decrease in temperature throughout the missing observations. Approximated temperature readings make up less than 0.3 percent of all observations for every station and, on average, represent under 0.1 percent of a station's hourly weather observations.

Stations CDS, COT, and SJT, were the only stations with borrowed observations that were more than 50 miles away from the actual station. Each of these stations was not used heavily in the analysis, having 1, 21, and 448 accounts involved in the treatment or comparison group, respectively. A visual inspection of the data showed a smooth transition between temperature data from the actual station and the borrowed stations.

When comparing with the tables below in the next section, we also see that our most common weather stations are complete with either their data or the data of a nearby station.

Station Details:

Table 73 shows the percentage of accounts assigned to each station in the treatment and comparison groups. The top stations are pretty similar across the treatment and comparison group, with the bulk of the observations coming from the Dallas metro area.

Table 73. Number and Percentage of Accounts Per ASOS Weather Station

Station	Treatment	Treatment Percentage	Comparison	Comparison Percentage	Overall	Overall Percentage
ADS	3,450	15.5%	3,449	17.8%	6,899	16.6%
RBD	3,275	14.7%	2,591	13.4%	5,866	14.1%
DFW	3,257	14.6%	1,496	7.7%	4,753	11.4%
DAL	2,009	9.0%	2,584	13.3%	4,593	11.0%
EBG	1,791	8.0%	1,192	6.1%	2,983	7.2%
NFW	548	2.5%	1,214	6.3%	1,762	4.2%
FTW	1,172	5.3%	506	2.6%	1,678	4.0%
NGP	512	2.3%	1,018	5.2%	1,530	3.7%
GVT	712	3.2%	745	3.8%	1,457	3.5%
ACT	632	2.8%	367	1.9%	999	2.4%
HRL	330	1.5%	532	2.7%	862	2.1%
IAH	663	3.0%	24	0.1%	687	1.6%
AFW	359	1.6%	243	1.3%	602	1.4%
HOU	463	2.1%	119	0.6%	582	1.4%
EFD	178	0.8%	326	1.7%	504	1.2%
SJT	257	1.2%	191	1.0%	448	1.1%
INK	174	0.8%	241	1.2%	415	1.0%
LRD	291	1.3%	101	0.5%	392	0.9%
ABI	255	1.1%	96	0.5%	351	0.8%
SPS	137	0.6%	210	1.1%	347	0.8%
GTU	171	0.8%	134	0.7%	305	0.7%
PSX	157	0.7%	140	0.7%	297	0.7%
BRO	83	0.4%	212	1.1%	295	0.7%
GLS	222	1.0%	47	0.2%	269	0.6%
TYR	84	0.4%	152	0.8%	236	0.6%
PWG	97	0.4%	127	0.7%	224	0.5%
MAF	81	0.4%	137	0.7%	218	0.5%
HLR	100	0.4%	104	0.5%	204	0.5%
PRX	6	0.0%	193	1.0%	199	0.5%
RBO	53	0.2%	136	0.7%	189	0.5%
TPL	64	0.3%	113	0.6%	177	0.4%
ILE	95	0.4%	76	0.4%	171	0.4%
NQI	101	0.5%	52	0.3%	153	0.4%
GRK	35	0.2%	113	0.6%	148	0.4%
ATT	72	0.3%	69	0.4%	141	0.3%
ALI	74	0.3%	30	0.2%	104	0.2%

Station	Treatment	Treatment Percentage	Comparison	Comparison Percentage	Overall	Overall Percentage
MRF	71	0.3%	23	0.1%	94	0.2%
DYS	57	0.3%	35	0.2%	92	0.2%
LFK	46	0.2%	45	0.2%	91	0.2%
MWL	23	0.1%	68	0.4%	91	0.2%
DWH	51	0.2%	5	0.0%	56	0.1%
OCH	10	0.0%	45	0.2%	55	0.1%
SSF	0	0.0%	36	0.2%	36	0.1%
RKP	7	0.0%	25	0.1%	32	0.1%
COT	18	0.1%	3	0.0%	21	0.1%
RFI	2	0.0%	16	0.1%	18	0.0%
DLF	5	0.0%	7	0.0%	12	0.0%
DRT	3	0.0%	6	0.0%	9	0.0%
CLL	3	0.0%	1	0.0%	4	0.0%
HDO	2	0.0%	1	0.0%	3	0.0%
CDS	1	0.0%	0	0.0%	1	0.0%
Total	**22,259**	**100.0%**	**19,396**	**100.0%**	**41,655**	**100.0%**

*Note: Totals may not sum to 100 percent due to rounding.

Lastly, Table 74 shows a reference of what specific station each station abbreviation represents.

Table 74. ASOS Abbreviation Definition

Station Abbreviation	ASOS Name	Station Abbreviation	ASOS Name	Station Abbreviation	ASOS Name
ABI	Abilene Municipal	EFD	Houston/Ellington	NFW	Fort Worth Nas
ACT	Waco	ELP	El Paso Intl Arpt	NGP	Corpus Christi Nas
ADS	Dallas/Addison Arpt	FTW	Fort Worth/Meacham	NQI	Kingsville Nas
AFW	Fort Worth - Alliance	GLS	Galveston/Scholes	OCH	Nacogdoches (Awos)
ALI	Alice Intl Airport	GRK	Fort Hood/Gray Aaf	PRX	Paris/Cox Field
AMA	Amarillo Arpt(Awos)	GTU	Georgetown (Awos)	PSX	Palacios Municipal
ATT	Austin	GVT	Greenville/Majors	PWG	Mc Gregor (Awos)
BPT	Beaumont/Port Arthu	HDO	Hondo Municipal	RBD	Dallas/Redbird Arpt
BRO	Brownsville Intl	HLR	Ft Hood Aaf/Killeen	RBO	Robstown
CDS	Childress Municipal	HOU	Houston/Will Hobby	RFI	Henderson
CLL	College Station	HRL	Harlingen Intl Arpt	RKP	Rockport/Aransas Co
COT	Cotulla Municipal	IAH	Houston/Intercontin	RND	Randolph Afb
DAL	Dallas/Love Field	ILE	Killeen Muni (Awos)	SAT	San Antonio Intl
DFW	Dallas/Ft Worth	INK	Wink/Winkler Co.	SJT	San Angelo/Mathis
DHT	Dalhart Municipal	LBB	Lubbock Intl Arpt	SKF	Kelly Afb
DLF	Laughlin Afb	LFK	Lufkin/Angelina Co.	SPS	Wichita Falls/Shep
DRT	Del Rio Intl (Aut)	LRD	Laredo Intl Airport	SSF	San Antonio/Stinson
DWH	Houston/D.W. Hooks	MAF	Midland Regional	TPL	Temple/Miller(Awos)
DYS	Dyess Afb/Abilene	MRF	Marfa Muni (Amos)	TYR	Tyler/Pounds Fld
EBG	Edinburg	MWL	Mineral Wells Muni	VCT	Victoria Regional

APPENDIX 1-B: SCREENING CRITERIA DETAILS

This appendix describes the screening criteria that were employed for the retrofit consumption analysis. We review the rules that were applied to exclude accounts from the analysis, step by step, stating the exclusionary condition, the reasoning, and analysis that informed the decision.

For each screening step, we present two tables summarizing the number of accounts affected. The first table shows the number of accounts remaining *after that step*, and the second table shows the number of accounts that were removed from the analysis *as a result of* that step. We also present tables at the end of this appendix that summarize the screening steps and the number of accounts affected at each step. Summary tables also show how screening affects accounts by TRM climate zone.

Defining the Pre- and Post-Periods:

Before enumerating the screening steps, we clarify the pre- and post-periods for measurement because these are different for the treatment and comparison groups. Some screening criteria deal with the dates of meter readings, which may differ for the two groups.

For the treatment group, the pre-period is 365 days *before* the participation date, and the post-period is 365 days *after* the participation date, including the participation date itself.

The comparison group is defined as future participants (PY2019 participants), and their pre- and post-periods are defined to construct a timeframe comparable to the treatment group during which energy consumption will be compared. Their PY2019 participation date is the reference point from which the pre- and post-periods are established. The pre-period is two years (730 days) before the 2019 participation date to 365 days before the participation date. The post-period is 365 days prior to the 2019 participation date. For example, if an account participated on January 1, 2019, its pre-period would be January 1, 2017 through December 31, 2017, while its post-period would be January 1, 2018 through December 31, 2018.

Four hundred thirty-eight accounts participated in the program in both 2018 and 2019. We include these as treatment group members only, focusing only on any measures received in 2018, provided that their 2019 participation date does not overlap with their post-period.

The Starting Number of Accounts:

As a starting point before any accounts are excluded, the tracking data include 33,567 treatment accounts and 29,785 comparison accounts. Table 75 presents the number of accounts by treatment or comparison status and utility. The 438 accounts mentioned above that are in both the treatment and comparison groups are included only in the treatment group frequencies.

Table 75. Number of Accounts by Treatment or Comparison Status and Utility

Starting	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	8,336	1,271	2,474	19,689	1,797	33,567
Comparison	7,420	928	2,092	17,539	1,806	29,785

Step 1: Accounts that Participated in Both 2018 and 2019. As mentioned in the introductory notes, 438 accounts participated in the program during both 2018 and 2019. These accounts are being included as part of the 2018 treatment group. We only include them if their 2019 participation date does not overlap with their post-period. For our first screening step, we check

that the 2019 treatment date is more than 365 days after the 2018 treatment date. Of the 438 accounts that were in both 2018 and 2019, 90 accounts qualified. The remaining 348 accounts were removed from the analysis. Table 76 and Table 77 present the results of this screening step.

Table 76. Accounts Remaining After Screening Step 1

Both Treatment and Comparison	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	8,188	1,268	2,330	19,636	1,797	33,219
Comparison	7,420	928	2,092	17,539	1,806	29,785

Table 77. Accounts Removed Due to Screening Step 1

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-148	-3	-144	-53	0	-348
Comparison	0	0	0	0	0	0

Step 2: Solar Interconnect Agreement. We exclude accounts that have a solar interconnect agreement. These accounts are removed from the analysis because their consumption may be misleading since they generate some or all of their own power. All utilities provide data on accounts with solar interconnect agreements. Table 78 and Table 79 present the results of this screening step.

Table 78. Accounts Remaining After Screening Step 2

Solar	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	8,085	1,265	2,329	19,501	1,795	32,975
Comparison	7,341	925	2,092	17,539	1,803	29,700

Table 79. Accounts Removed Due to Screening Step 2

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-103	-3	-1	-135	-2	-244
Comparison	-79	-3	0	0	-3	-85

Step 3: Account in Tracking Data but not in Meter Data. For each utility, some accounts were in the tracking data but were not in the meter data. As can be seen by the number of accounts that were removed for each utility, not many accounts were removed from consideration for this reason, with the CenterPoint comparison group being the exception. There was a missing file for LI program participants from 2019 that was never received. Despite this missing data, the LI program still had over 1,000 comparison group accounts. Table 80 and Table 81 present the results of this screening step.

Table 80. Accounts Remaining After Screening Step 3

No Meter	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	8,079	1,265	2,329	19,495	1,795	32,963
Comparison	7,326	924	652	17,532	1,803	28,237

Table 81. Accounts Removed Due to Screening Step 3

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-6	0	0	-6	0	-12
Comparison	-15	-1	-1,440	-7	0	-1,463

Step 4: Inadequate Minimum and Maximum Date Ranges. We examine the minimum and maximum date that meter data was recorded for an account. If the minimum or maximum meter reading date would result in the pre- or post-period for an account not being a full year, the account is screened out. To provide an example, if an account's pre-period should start on January 1, 2017, but the first recorded meter reading comes after that date, the account is screened out due to the pre-period being too short. As shown below, AEP TCC loses 641 treatment group accounts; however, other utilities all lose less than 100 accounts. Table 82 and Table 83 present the results of this screening step.

Table 82. Accounts Remaining After Screening Step 4

Date Range	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	7,438	1,252	2,318	19,445	1,747	32,200
Comparison	7,178	888	651	17,531	1,764	28,012

Table 83. Accounts Removed Due to Screening Step 4

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-641	-13	-11	-50	-48	-763
Comparison	-148	-36	-1	-1	-39	-225

Some accounts have multiple measures with different installation dates—506 (1.5 percent) treatment accounts and 849 (3 percent) comparison accounts. We require these accounts to have a year on each side of each measure for the treatment group. For the treatment group, the dates between are not used in the analysis and are effectively *blacked out*.[24] In other words, the pre-period is defined as the 365 days before the *first* installation, and the post-period is defined as the 365 days after the *last* installation. Because of how the comparison group pre- and post-period is structured, this does not affect the comparison group. The comparison group periods continue to be the two years preceding the *first* installation.

Step 5: Gaps in Meter Data During the Pre- or Post-Period. We exclude accounts that are missing more than one day of meter reads across the entire period (i.e., 96 15-minute intervals).[25] We retain cases with up to one day of missing meter reads to preserve the number of cases available for analysis, and this rule kept the amount of missing data in the pre- and post-periods consistent.

Among the accounts missing up to one day of data overall, 80 percent of treatment group accounts and 76 percent of comparison group accounts did not have a consecutive period greater than one hour (four 15-minute meter reads) of missing data. Ninety-nine percent (treatment group) and 97 percent (comparison group) did not have a consecutive run of missing data greater than 4 hours (sixteen 15-minute meter reads). While there are streaks of missing data as short as one 15-minute interval, every account that is missing data has a max consecutive missing streak of at least an hour.

Our analysis showed that allowing a greater amount of missing data did not appreciably increase the number of cases in the analysis group and would require imputing many observations. We gain only 2,120 accounts (from 52,700 to 54,820) if accounts with up to one

[24] The mean number of days between two measures for accounts that ended up qualifying for our analysis was about 34 days with a max of 165. Ultimately, since we do have a full year of data on each side of the measure dates, we do not remove any accounts for this reason.

[25] We do not know how the 2014 consumption analysis handled missing data other than the fact that some accounts were removed due to missing data

week (672 15-minute meter reads) of missing meter reads are retained. Table 84 and Table 85 present the results of this screening step.

Table 84. Accounts Remaining After Screening Step 5

Missing	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	4,518	813	2,308	19,445	1,699	28,783
Comparison	4,121	528	230	17,530	1,508	23,917

Table 85. Accounts Removed Due to Screening Step 5

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-2,920	-439	-10	0	-48	-3,417
Comparison	-3,057	-360	-421	-1	-256	-4,095

Step 6: Meter Readings of Zero kWh in the Pre- or Post-Period. We exclude cases with more than one month (total across the period, 2,880 total meter reads) of zero kWh readings or more than one consecutive week (672 consecutive 15-minute meter reads) of zero kWh readings. As described below, this rule retains accounts between the 80th and 90th percentiles and below when examining the distribution of cases based on the total number of zero kWh readings and the longest consecutive run of zero kWh readings.

Zero kWh readings are quite common in the data, and this step removed 5,741 accounts from the treatment group and 4,101 accounts from the comparison group. This is a significant amount of removed accounts (about 17 percent for the treatment group and 14 percent for the comparison group) but is quite similar to the amount removed from this step last time this analysis was completed (about 15 percent).

As can be seen in Table 86 and Table 87, the distribution of meter readings of zero kWh is quite similar for the treatment and comparison group. While it is not included below, after we exclude the accounts that meet the rule for exclusion, the distribution of zero kWh readings from treatment to comparison remains very similar.

Table 86. Total Meter Readings of Zero kWh by Percentile (Numbers in Days)

Total Zeros (In Days)											
Percentile	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Treatment	0.01	0.08	0.14	0.21	0.32	0.53	1.17	3.8	11.16	36.41	729.91
Comparison	0.01	0.09	0.15	0.21	0.32	0.49	0.96	3.13	7.75	29.75	729.91

Table 87. Longest Streak of Meter Readings of Zero kWh by Percentile (Numbers in Days)

Maximum Streak of Zeros (In Days)											
Percentile	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Treatment	0.01	0.04	0.04	0.07	0.11	0.2	0.35	1.11	5.48	18.59	363.96
Comparison	0.01	0.04	0.05	0.07	0.11	0.19	0.35	1.01	4.21	14	401.3

There can be multiple reasons for meter readings of zero kWh. They include using no power for a 15-minute period, complete vacancy (extended streaks of zero kWh), brief power outages, shutting down power for work on a home, and meter reading failure. Meter readings of zero kWh are quite common in the data; few accounts have no zero kWh meter readings across the period of analysis.

Overall, there does not appear to be anything systematic about the timing of zero kWh readings.[26] The dates that are the most commonly associated with zero kWh readings are not related to Hurricane Harvey, which is something that we considered. Table 88 and Table 89 present the results of this screening step.

Table 88. Accounts Remaining After Screening Step 6

Zeros	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	3,460	621	1,358	16,376	1,227	23,042
Comparison	3,598	420	83	14,310	1,405	19,816

Table 89. Accounts Removed Due to Screening Step 6

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-1058	-192	-950	-3069	-472	-5741
Comparison	-523	-108	-147	-3220	-103	-4101

Step 7: Drastic Changes in total Pre- and Post-Consumption. We exclude accounts with a change in consumption that was in excess of 70 percent in magnitude. This approach follows the same rule applied in the 2014 consumption analysis.

The histograms below show the distribution of changes in consumption from the pre- to post-period. There were 159 treatment accounts and 194 comparison accounts that had changes in excess of 100 percent that are not displayed in the histograms. Table 90 and Table 91 present the results of this screening step.

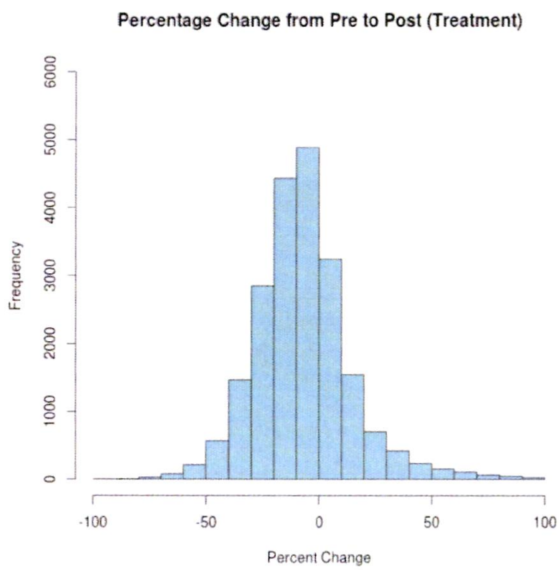
Table 90. Accounts Remaining After Screening Step 7

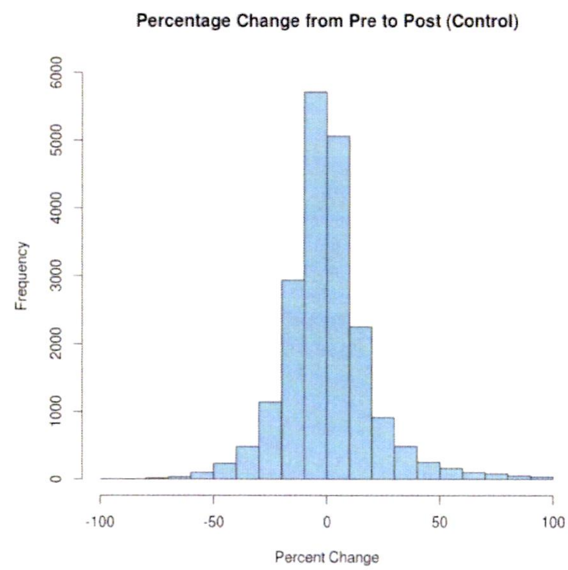
Percentage of Change	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	3,423	609	1,345	16,115	1,198	22,690
Comparison	3,476	400	83	14,108	1,362	19,429

Table 91. Accounts Removed Due to Screening Step 7

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-37	-12	-13	-261	-29	-352
Comparison	-122	-20	0	-202	-43	-387

[26] Other than zeros associated with Daylight Savings Time, there are not any dates that have a markedly higher frequency of zero readings for either the treatment or comparison group.





Step 8: Projected Project Savings are Greater than 100 Percent or Less Than 1 Percent of Pre-Period Usage:

We exclude minor accounts (those with projected savings less than one percent of pre-period consumption). We also exclude projects where the projected savings could not possibly happen, or the pre-period consumption is low enough that savings may not be representative of typical savings (projected savings are greater than 100 percent of pre-period consumption). This approach follows the same rule applied to the 2014 consumption analysis.

This screening step applies to the treatment group only. The histogram below shows the project size as a percentage of the pre-period consumption for each treatment group household. Table 92 and Table 93 present the results of this screening step.

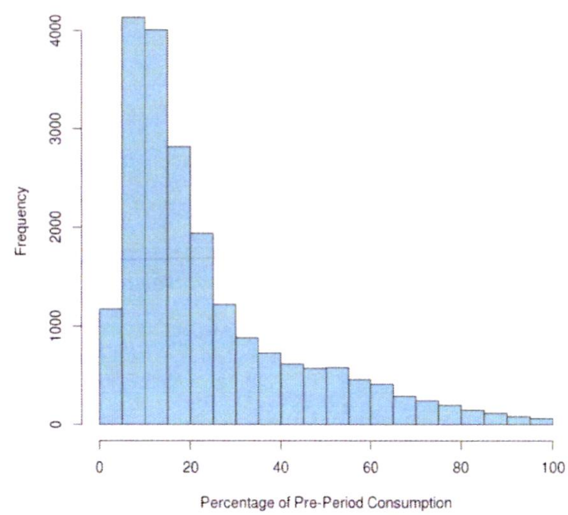
Table 92. Accounts Remaining After Screening Step 8

Project Size	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	3,416	606	1,308	15,791	1,174	22,295
Comparison	3,476	400	83	14,108	1,362	19,429

Table 93. Accounts Removed Due to Screening Step 8

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-7	-3	-37	-324	-24	-395
Comparison	0	0	0	0	0	0

Estimated Savings Divided by Pre Period Consumption (Treatment)



Step 9: Total Usage in the Pre- or Post-Period is Drastically Below or Above the Average Consumption. We exclude accounts that consumed less than 1,000 kWh in the pre- or post-period or more than 70,000 kWh in the pre- or post-period. Consumption beyond these levels occurs rarely, and we do not feel it is representative of typical residential consumption as it is either less than seven percent of, or nearly five times the mean level.

The average pre-period consumption for accounts remaining in the analysis set after applying the previous screening steps is 15,383 kWh for the treatment group and 16,241 kWh for the comparison group. The post period is 13,652 kWh for the treatment group and 15,983 kWh for the comparison group.

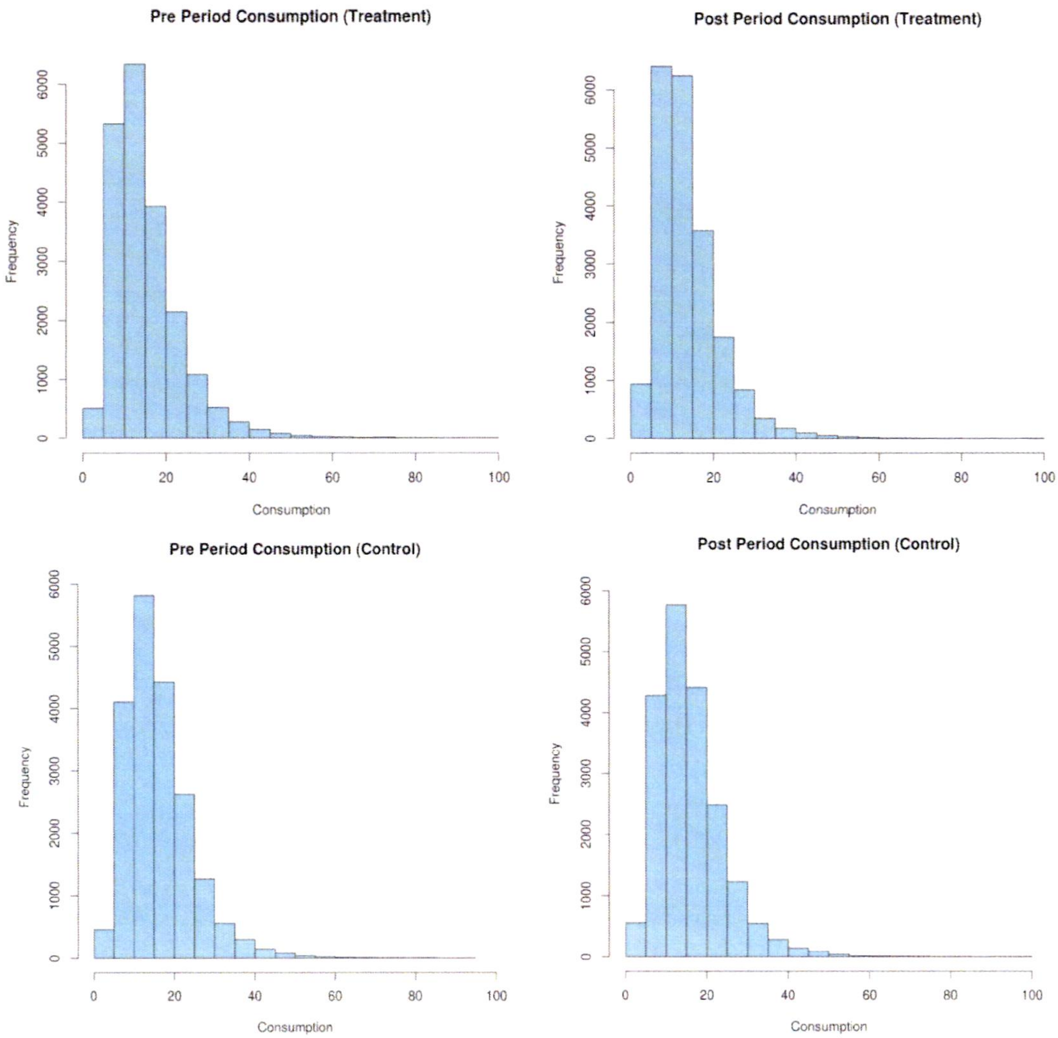
A histogram showing what the distribution looked like before these accounts were removed is shown below for both the pre- and post-period for treatment and comparison groups. To make them readable, a few accounts over 100,000 kWh were removed before plotting the histogram. Table 94 and Table 95 present the results of this screening step.

Table 94. Accounts Remaining After Screening Step 9

Total kWh	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	3,415	606	1,308	15,756	1,174	22,259
Comparison	3,475	399	83	14,077	1,362	19,396

Table 95. Accounts Removed Due to Screening Step 9

Difference	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	-1	0	0	-35	0	-36
Comparison	-1	-1	0	-31	0	-33



Final Number of Accounts:

Table 96 and Table 97 present the final number of accounts for each screening step described above, first for the treatment group and then the comparison group. Overall, our total remaining percentage of about 66 percent of treatment group accounts and 65 percent of comparison group accounts is quite similar to the 2014 consumption analysis, where they had about 63 percent of treatment accounts and nearly 70 percent of comparison group accounts. We also include the screening results by TRM climate zone in Table 98 and Table 99.

Table 96. Model Screening Steps By Utility, Treatment

Treatment	AEP TCC	AEP TNC	CP	Oncor	TNMP	Total	Percentage Remaining
Starting	8,336	1,271	2,474	19,689	1,797	33,567	100.0%
Both Treatment and Comparison	8,188	1,268	2,330	19,636	1,797	33,219	99.0%
Solar	8,085	1,265	2,329	19,501	1,795	32,975	98.2%
No Meter	8,079	1,265	2,329	19,495	1,795	32,963	98.2%

Treatment	AEP TCC	AEP TNC	CP	Oncor	TNMP	Total	Percentage Remaining
Date Range	7,438	1,252	2,318	19,445	1,747	32,200	95.9%
Missing	4,518	813	2,308	19,445	1,699	28,783	85.7%
Zeros	3,460	621	1,358	16,376	1,227	23,042	68.6%
Percentage Change	3,423	609	1,345	16,115	1,198	22,690	67.6%
Project Size	3,416	606	1,308	15,791	1,174	22,295	66.4%
Total kWh	3,415	606	1,308	15,756	1,174	22,259	**66.3%**
Percentage by Utility	**41.0%**	**47.7%**	**52.9%**	**80.0%**	**65.3%**	-	-

Table 97. Model Screening Steps by Utility, Comparison

Comparison	AEP TCC	AEP TNC	CP	Oncor	TNMP	Total	Percentage Remaining
Starting	7,420	928	2,092	17,539	1,806	29,785	100.0%
Both Treatment and Comparison	7,420	928	2,092	17,539	1,806	29,785	100.0%
Solar	7,341	925	2,092	17,539	1,803	29,700	99.7%
No Meter	7,326	924	652	17,532	1,803	28,237	94.8%
Date Range	7,178	888	651	17,531	1,764	28,012	94.0%
Missing	4,121	528	230	17,530	1,508	23,917	80.3%
Zeros	3,598	420	83	14,310	1,405	19,816	66.5%
Percentage Change	3,476	400	83	14,108	1,362	19,429	65.2%
Project Size	3,476	400	83	14,108	1,362	19,429	65.2%
Total kWh	3,475	399	83	14,077	1,362	19,396	**65.1%**
Percentage by Utility	**46.8%**	**43.0%**	**4.0%**	**80.3%**	**75.4%**	-	-

Figure 39. Map of Technical Reference Manual Climate Zones

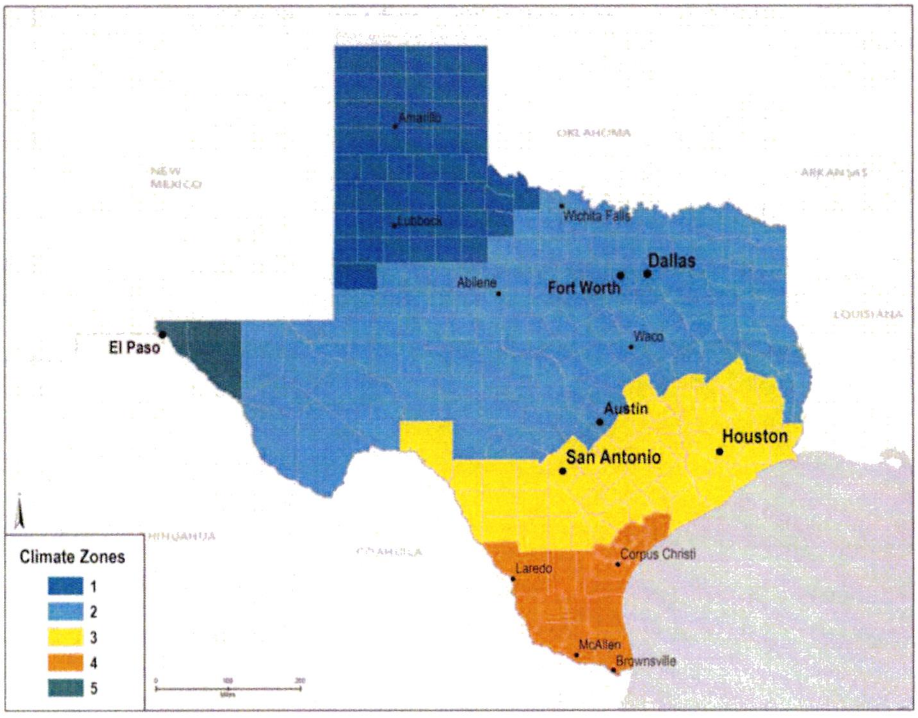


Table 98. Model Screening Steps by Climate Zone, Treatment

Treatment	1	2	3	4	5	Total	Percentage Remaining
Starting	21	22,182	3,305	8,051	8	33,567	100.0%
Both Treatment and Comparison	21	22,126	3,118	7,946	8	33,219	99.0%
Solar	21	21,987	3,116	7,843	8	32,975	98.2%
No Meter	21	21,981	3,114	7,839	8	32,963	98.2%
Date Range	21	21,870	3,099	7,202	8	32,200	95.9%
Missing	9	21,411	3,010	4,348	5	28,783	85.7%
Zeros	6	17,926	1,786	3,319	5	23,042	68.6%
Percentage Change	6	17,629	1,766	3,284	5	22,690	67.6%
Project Size	6	17,279	1,726	3,279	5	22,295	66.4%
Total kWh	6	17,244	1,726	3,278	5	22,259	**66.3%**
Percentage By Utility	**28.6%**	**77.7%**	**52.2%**	**40.7%**	**62.5%**	-	-

Table 99. Model Screening Steps by Climate Zone, Comparison

Comparison	1	2	3	4	5	Total	Percentage Remaining
Starting	155	19,510	3,106	7,014	0	29,785	100.0%
Both Treatment and Comparison	155	19,510	3,106	7,014	0	29,785	100.0%
Solar	155	19,504	3,104	6,937	0	29,700	99.7%
No Meter	154	19,497	1,661	6,925	0	28,237	94.8%
Date Range	141	19,435	1,652	6,784	0	28,012	94.0%
Missing	100	18,939	968	3,910	0	23,917	80.3%
Zeros	79	15,588	722	3,427	0	19,816	66.5%
Percentage Change	72	15,338	699	3,320	0	19,429	65.2%
Project Size	72	15,338	699	3,320	0	19,429	65.2%
Total kWh	72	15,306	699	3,319	0	19,396	**65.1%**
Percentage by Utility	**46.5%**	**78.5%**	**22.5%**	**47.3%**	**0.0%**	-	-

APPENDIX 1-C: MODEL SPECIFICATIONS, DETAILS, AND RESULTS

Individual Household Weather Normalization Models:

The following model was used to estimate weather-normalized consumption in the pre- and post-period for each account. This model was run for each treatment group and comparison group account, with a separate model performed for the pre- and post-period as well. For each household, the model was run with every possible combination of cooling degree hour (65-85 degrees) and heating degree hour setpoints (45-65 degrees), for a total of 441 regressions run for each account in both the pre- and post-period. Once all 441 models were complete, model coefficients were saved for the model with the most explanatory power (highest R^2).

Equation 1. Individual Household Weather Normalization Model

$$Hourly\ Consumption_{it} = \alpha_i + \beta_1 HDH_{it} + \beta_2 CDH_{it} + \beta_3 Hour\_1_{it} + \cdots + \beta_{25} Hour\_23_{it}$$

Where for each customer 'I' and hour of the year 't':

$Hourly\ Consumption_{it}$ = Actual hourly consumption in the pre- or post-program period

α_i = The participant intercept, representing the kWh baseload at hour 0 of the day

β_1 = The model heating slope, representing the average change in hourly usage resulting from an increase of one HDH

HDH_{it} = The base 45-65 HDH for the nearest weather station calculated as:

$$HDH_{it} = Base_{45-65} - Temperature_{it}$$

Where HDH_{it} is greater than 0, else $HDH_{it} = 0$

β_2 = The model cooling slope, representing the average change in hourly usage resulting from an increase of one CDH

CDH_{it} = The base 65-85 CDH for the nearest weather station calculated as:

$$CDH_{it} = Temperature_{it} - Base_{65-85}$$

Where CDH_{it} is greater than 0, else $CDH_{it} = 0$

β_{3-25} = Additional intercepts for each hour of the day, representing the kWh baseload at hour 1-23 of the day

$Hour\_1_{it}$ = Dummy variable indicating the hour of the day. There are variables for Hour_1 through Hour_23

Additional steps to get savings estimates:

Upon completion of the above models, we had *CDH*, *HDH*, and *hour_1-23* coefficients for each account in the pre- and post-period. The account was then matched with its nearest TMY3 station. Distance between stations was calculated using latitude and longitude, finding the closest station *as the crow flies*. CDH and HDH were then calculated for that TMY3 station based on the optimal setpoints of the specific account's models.

Once CDH and HDH were calculated for the TMY3 station, the TMY3 data was then fit to the model, yielding a weather-normalized consumption estimate for every hour of the pre- and post-period for each account. The hourly estimates of the pre- and post-period were then summed within their period, resulting in the normalized annual consumption for the pre- and post-period. At this point, we can take the difference between the pre- and post-period normalized annual consumption to get our savings estimates for each household.

Now that we have a savings estimate for every account, we average the savings over the treatment and comparison groups to come to overall savings at the program level. We do this by subtracting the average comparison group savings from the average treatment group savings. We also segment our data by program and perform this same calculation to arrive at savings estimates for each program.

The methods described above also allow us to look at savings on the measure level through the techniques presented below. To do this, we match the savings for each account up with binary variables representing the measures that the account received. We then use the following regression model to estimate the measure level savings. This model was chosen based on section 4.3.2.2 of the Uniform Methods Project. This model and our *measure-level fixed-effects* model provide similar estimates; however, this modeling technique offers more flexibility in weather modeling.

Equation 2. Measure Savings Regression Model

$$Change\ in\ NAC_i = \alpha_i + \beta_1 AC_i + \beta_2 Air\_Inf_i + \beta_3 Ceiling\_Ins_i + \beta_4 Duct\_Eff_i + \beta_5 Floor\_Ins_i + \beta_6 Heat\_Pump_i + \beta_7 Solar\_Screen_i + \beta_8 Wall\_Ins_i + \beta_9 Window_i + \beta_{10} Window\_AC_i$$

$Change\ in\ NAC_i$ = The change in weather-normalized consumption as calculated from the model and methods described above

α_i = The model intercept, representing the average $Change\ in\ NAC$ for the comparison group

β_1 =The deviation from α_i for accounts that received an *AC* measure, representing the average kWh savings among accounts that received an *AC* measure, holding constant all other measure installations

AC_i =A binary variable equal to 1 if an account received an *AC* measure and 0 if they did not

These definitions remain the same for all other coefficients and independent variables; however, each independent variable represents a different measure. This model gives us the change associated with each measure as well as the change associated with the comparison group. This way, we can separate program effects from non-program effects associated with the change in the comparison group. Measure results calculated based on this model are seen in the report where findings are significant. The complete results are shown below in Table 100, Table 101, Table 102, and Table 103. Following that, there is a section on model goodness of fit.

Table 100. Individual Household Weather-Normalization Model Measure-Level Results, Overall

Overall	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre	TRM Compared to Pre
AC	3,605	19,602	2,235	2,951	3.6%	75.7%	11.4%	15.1%
Air Infiltration	10,898	13,171	31	1,334	184.9%	2.3%	0.2%	10.1%
Ceiling Insulation	4,267	15,164	651	2,514	11.4%	25.9%	4.3%	16.6%
Duct Sealing	2,759	15,671	387	674	25.0%	57.4%	2.5%	4.3%
Heat Pump	4,611	15,564	2,728	6,412	2.7%	42.5%	17.5%	41.2%
Other Recorded Measures								
Solar Screen	19	11,604	-686	309	-150.9%	-221.7%	-5.9%	2.7%
Wall Insulation	107	13,637	1,319	1,153	33.4%	114.4%	9.7%	8.5%
Window	47	14,023	-8	591	-8,592.2%	-1.3%	-0.1%	4.2%
Window AC	1	14,157	2,790	613	162.3%	454.9%	19.7%	4.3%
Floor Insulation	2	11,967	-1,340	195	-237.8%	-687.6%	-11.2%	1.6%

Table 101. Individual Household Weather-Normalization Model Measure-Level Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre	TRM Compared to Pre
AC	3,579	19,654	2,229	2,961	4.0%	75.3%	11.3%	15.1%
Air Infiltration	6,306	12,961	-62	1,363	127.1%	-4.6%	-0.5%	10.5%
Ceiling Insulation	1,778	15,977	615	3,552	19.0%	17.3%	3.9%	22.2%
Duct Sealing	1,970	15,466	383	668	31.9%	57.3%	2.5%	4.3%
Heat Pump	2,496	19,145	3,160	7,078	3.3%	44.6%	16.5%	37.0%
Other Recorded Measures								
Solar Screen	2	13,033	3,306	136	99.9%	2426.4%	25.4%	1.0%
Wall Insulation	3	14,697	-3,133	689	-86.1%	-455.0%	-21.3%	4.7%
Window	19	15,037	-1,411	813	-76.0%	-173.5%	-9.4%	5.4%

Table 102. Individual Household Weather-Normalization Model Measure-Level Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre	TRM Compared to Pre
AC	17	13,427	2,070	1,345	49.3%	153.9%	15.4%	10.0%
Air Infiltration	4,445	13,474	179	1,328	45.7%	13.4%	1.3%	9.9%
Ceiling Insulation	2,222	14,830	617	1,889	16.0%	32.7%	4.2%	12.7%
Duct Sealing	775	16,146	471	695	34.9%	67.7%	2.9%	4.3%
Heat Pump	659	12,763	2,653	6,134	6.4%	43.2%	20.8%	48.1%
Other Recorded Measures								
Solar Screen	2	12,002	565	166	526.1%	340.4%	4.7%	1.4%
Wall Insulation	7	11,256	419	954	379.6%	44.0%	3.7%	8.5%
Window	5	5,322	-1,554	383	-121.5%	-406.0%	-29.2%	7.2%
Floor Insulation	1	7,512	-3,336	195	-126.1%	-1711.6%	-44.4%	2.6%

Table 103. Individual Household Weather-Normalization Model Measure-Level Results, Low-Income

LI	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings Compared to Pre	TRM Compared to Pre
AC	10	11,595	1,872	2,211	75.3%	84.7%	16.1%	19.1%
Air Infiltration	173	14,130	113	613	336.7%	18.3%	0.8%	4.3%
Ceiling Insulation	300	13,231	950	1,083	30.1%	87.7%	7.2%	8.2%
Duct Sealing	21	17,578	621	460	151.1%	135.1%	3.5%	2.6%
Heat Pump	1,467	10,681	1,868	5,386	8.4%	34.7%	17.5%	50.4%
Other Recorded Measures								
Solar Screen	15	11,360	-1,542	352	-76.3%	-438.7%	-13.6%	3.1%
Wall Insulation	97	13,776	1,218	1,182	38.5%	103.1%	8.8%	8.6%
Window	28	13,336	702	440	115.9%	159.5%	5.3%	3.3%
Window AC	1	14,157	2,371	613	178.3%	386.6%	16.7%	4.3%
Floor Insulation	1	16,421	1,147	237	366.8%	484.4%	7.0%	1.4%

Table 104 and Table 105 show the distribution of R^2 for first the pre- and then the post-period. The average R^2 for both the treatment and comparison group was about 0.4 in both the pre- and post-period. There are histograms as well, with the treatment group in blue and the comparison group in red.

Table 104. Individual Household Weather-Normalization Model R^2 Distribution, Pre-Period

R^2	Treatment Number of Accounts	Treatment % of Accounts	Comparison Number of Accounts	Comparison % of Accounts
0-0.1	554	2.5%	326	1.7%
0.1-0.2	2,426	10.9%	1,859	9.6%
0.2-0.3	3,541	15.9%	3,196	16.5%
0.3-0.4	4,266	19.2%	3,776	19.5%
0.4-0.5	4,209	18.9%	3,646	18.8%
0.5-0.6	3,425	15.4%	3,031	15.6%
0.6-0.7	2,401	10.8%	2,006	10.3%
0.7-0.8	1,208	5.4%	1,274	6.6%
0.8-0.9	229	1.0%	281	1.4%
0.9-1	0	0.0%	1	0.0%
Total	**22,259**	**100.0%**	**19,396**	**100.0%**

Table 105. Individual Household Weather-Normalization Model R^2 Distribution, Post-Period

R^2	Treatment Number of Accounts	Treatment % of Accounts	Comparison Number of Accounts	Comparison % of Accounts
0-0.1	800	3.6%	544	2.8%
0.1-0.2	3,013	13.5%	2,351	12.1%
0.2-0.3	3,934	17.7%	3,453	17.8%
0.3-0.4	4,393	19.7%	3,693	19.0%
0.4-0.5	3,740	16.8%	3,371	17.4%
0.5-0.6	2,859	12.8%	2,467	12.7%
0.6-0.7	2,033	9.1%	1,905	9.8%
0.7-0.8	1,204	5.4%	1,254	6.5%
0.8-0.9	283	1.3%	357	1.8%
0.9-1	0	0.0%	1	0.0%
Total	**22,259**	**100.0%**	**19,396**	**100.0%**

Figure 40. Treatment Group R^2 Distributions, Pre-Period

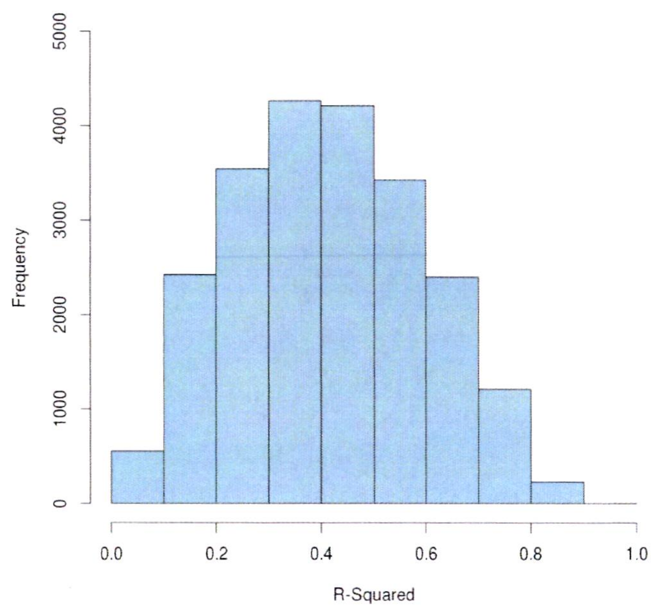


Figure 41. Treatment Group R^2 Distributions, Post-Period

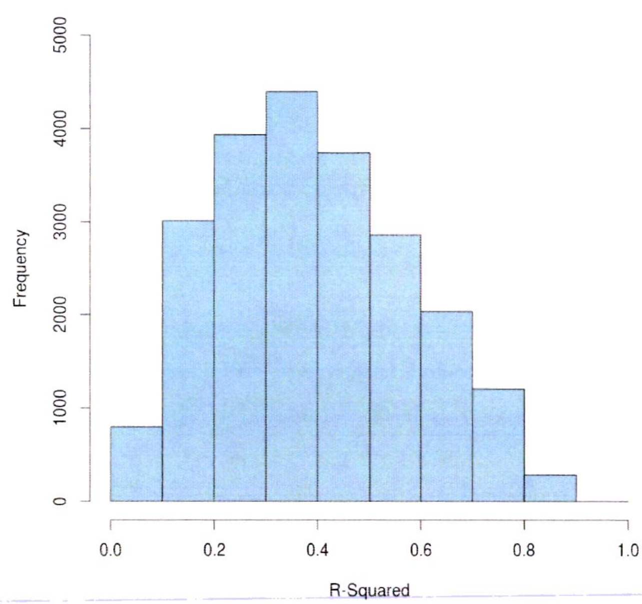


Figure 42. Comparison Group R^2 Distributions, Pre-Period

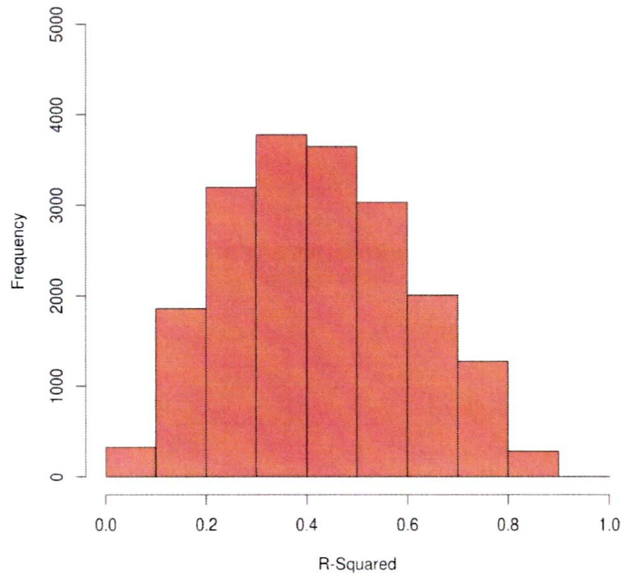
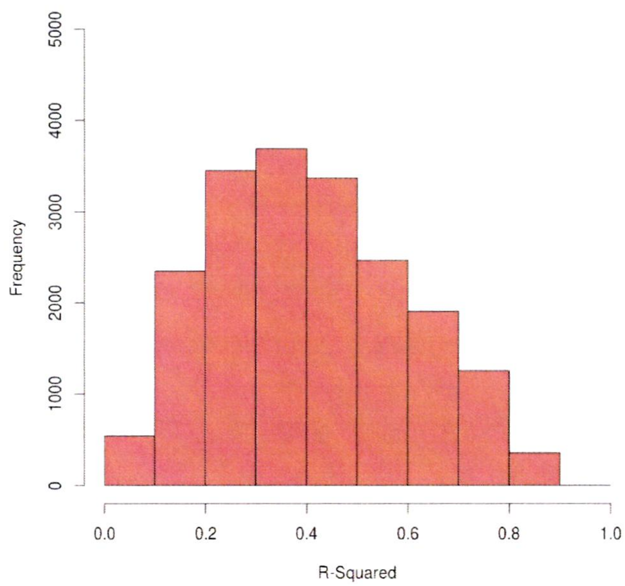


Figure 43. Comparison Group R^2 Distributions, Post-Period



Program-Level Fixed-Effect Models:

The following model was used to estimate the change in weather-normalized consumption from the pre- to post-period at the program level. It provides a result that is similar to our individual household models and acts as a backup model to validate the results of our individual household models. This model was run with the data in a daily format and with the average heating and cooling setpoints from the individual household models, 70 and 56. This model was inspired by the 2014 consumption analysis, where the average setpoints were 69 and 54.

Equation 3. Program-Level Fixed-Effect Model

$$Daily\ Consumption_{it} = \beta_1 HDD_{it} + \beta_2 CDD_{it} + \beta_3 post_{it} + \beta_4 HDD_{it} * post_{it} + \beta_5 CDD_{it} * post_{it} + esiid_{it}$$

Where for each customer 'i' and day of the year 't':

$Daily\ Consumption_{it}$	=	Actual daily consumption in the pre- or post-program period
$esiid_i$	=	The participant account number, representing the daily kWh baseload for each account; effectively, this is the intercept of account 'i'
β_1	=	The average change in daily usage resulting from an increase of one HDD in the pre-period
HDD_{it}	=	The base 56 HDDs for the nearest weather station
β_2	=	The average change in daily usage resulting from an increase of one CDD in the pre-period
CDD_{it}	=	The base 70 CDDs for the nearest weather station
β_3	=	The average baseload savings in the post-period
$post_{it}$	=	An indicator variable that equals 1 in the post-period (after the final measure installation for that account) and 0 in the pre-period (prior to any measure installation for that account)
β_4	=	The average savings in daily usage per HDD in the post-period
$HDD_{it} * post_{it}$	=	An interaction term between HDD and the post-indicator variable
β_5	=	The average savings in daily usage per CDD in the post-period
$CDD_{it} * post_{it}$	=	An interaction term between CDD and the post-indicator variable

Once the model has been run for a program, we fit the average annual TMY3 CDD and HDD for that segment to our model coefficients that contain the *post*-term and then multiply the *post*-term by 365 since this coefficient is at the daily level. Summing those results yields our annual savings estimate. We do this for both the treatment and comparison group and difference the *Savings as a Percentage of PRENAC* column to come to our final adjusted model savings. This differencing approach and this model were used mainly as a confirmation of our individual household models and to replicate the previous consumption analysis. The complete results are shown below in Table 106, Table 107, Table 108, and Table 109.

Table 106. Program-Level Fixed-Effect Model Results, Overall

Overall	n	PRENAC	Model Savings (kWh)	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Precision at 90%	Savings Lower 90%	Savings Upper 90%
Treatment	22,259	15,004	1,214	3,032	40.0%	8.1%	±3.34%	1,174	1,255
Comparison	19,396	15,891	86	-	-	0.5%	±49.88%	43	129
Adjusted Gross	22,259	15,004	1,133	3,032	37.4%	7.6%	±7.36%	1,050	1,217

Table 107. Program-Level Fixed-Effect Model Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings (kWh)	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Precision at 90%	Savings Lower 90%	Savings Upper 90%
Treatment	13,988	16,067	1,338	3,182	42.1%	8.3%	±4.4%	1,280	1,397
Comparison	10,986	17,185	131	-	-	0.8%	±45.6%	71	191
Adjusted Gross	13,988	16,067	1,216	3,182	38.2%	7.6%	±9.3%	1,103	1,329

Table 108. Program-Level Fixed-Effect Model Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings (kWh)	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Precision at 90%	Savings Lower 90%	Savings Upper 90%
Treatment	6,501	13,771	716	2,263	31.6%	5.2%	± 1.2%	708	724
Comparison	7,430	14,167	45	-	-	0.3%	±137.3%	17	108
Adjusted Gross	6,501	13,771	716	2,263	31.6%	5.2%	±1.2%	708	724

Table 109. Program-Level Fixed-Effect Model Results, Low-Income

LI	n	PRENAC	Model Savings (kWh)	TRM Savings (kWh)	Savings as Percentage of TRM	Savings as Percentage of PRENAC	Precision at 90%	Savings Lower 90%	Savings Upper 90%
Treatment	1,808	11,255	2,038	4,700	43.4%	18.1%	±5.8%	1,921	2,156
Comparison	1,274	13,260	226	-	-	1.7%	±68.7%	71	381
Adjusted Gross	1,808	11,255	1,846	4,700	43.4%	16.4%	±14.8%	1,574	2,119

Measure-Level Fixed-Effects Models:

The following model was used to estimate the change in weather-normalized consumption from the pre- to post-period at the measure level. It provides a result that is similar to our individual household models and acts as a backup model to validate the results of our individual household models. This model was run with the data in a daily format and with the average heating and cooling setpoints from the individual household models, 70 and 56. To keep the specification shorter, the model specification below shows just one measure; however, all interaction variables shown below are repeated for each measure in the actual model specification.

Equation 4. Measure Level Fixed-Effect Model

$$Daily\ Consumption_{it} = \beta_1 AC_{it} * HDD_{it} + \beta_2 AC_{it} * CDD_{it} + \beta_3 AC_{it} * post_{it} + \beta_4 AC_{it} * HDD_{it} * post_{it} + \beta_5 AC_{it} * CDD_{it} * post_{it} + esiid_{it}$$

Where for each customer 'i' and day of the year 't':

$Daily\ Consumption_{it}$	=	Actual daily consumption in the pre- or post-program period
$esiid_i$	=	The participant account number, representing the daily kWh baseload for each account; effectively, this is the intercept of account 'i'
β_1	=	The average change in daily usage resulting from an increase of one HDD in the pre-period for accounts that received an AC unit
$AC_{it} * HDD_{it}$	=	The base 56 HDDs for the nearest weather station multiplied by the AC indicator variable (1 if the account received an AC measure, 0 if not)
β_2	=	The average change in daily usage resulting from an increase of one CDD in the pre-period for accounts that received an AC unit
$\beta_2 AC_{it} * CDD_{it}$	=	The base 70 CDD for the nearest weather station multiplied by the AC indicator variable
β_3	=	The average baseload savings in the post-period for accounts that received an AC measure
$\beta_3 AC_{it} * post_{it}$	=	An indicator variable that equals 1 in the post-period (after the final measure installation for that account) and 0 in the pre-period (prior to any measure installation for that account) multiplied by the AC indicator variable
β_4	=	The average savings in daily usage per HDD in the post-period for accounts that received an AC measure
$AC_{it} * HDD_{it} * post_{it}$	=	An interaction term between HDD and the post-indicator variable multiplied by the AC indicator variable
β_5	=	The average savings in daily usage per CDD in the post-period for accounts that received an AC measure
$AC_{it} * CDD_{it} * post_{it}$	=	An interaction term between CDD and the post-indicator variable multiplied by the AC indicator variable

Once the model has been run for a program, we fit the average annual TMY3 CDD and HDD for that segment and measure group to our model coefficients that contain the *post*-term and multiply the *post*-term by 365 since this coefficient is at the daily level. Summing those results yields our annual savings estimate for that measure. We do this for the treatment group and difference out the comparison group savings estimate that was calculated by the program-level fixed-effects model, which brings us to our final adjusted model savings for each measure. We look at changes in consumption at the program level rather than the measure level for the comparison group because the comparison group accounts have not actually received a measure during the time period of this analysis. This model was used mainly as a confirmation of our individual household models and to replicate the previous consumption analysis. Where we have a large enough sample size, model results are quite consistent. Complete results are below (Table 110, Table 111, Table 112, and Table 113), as well as comparisons to our reported measure-level results from the *individual household weather-normalization* models (Table 114, Table 115, Table 116, and Table 117). While the results of these models differ by up to approximately 52 percent for the core measures of this analysis in the RSOP and HTR SOP, the overall result of the analysis compared to TRM averages remains consistent.

Table 110. Measure-Level Fixed-Effect Model Results, Overall

Overall	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	3,605	19,602	2,237	2,951	5.0%	75.8%	11.4%	15.1%
Air Infiltration	10,898	13,171	22	1,334	326.9%	1.7%	0.2%	10.1%
Ceiling Insulation	4,267	15,164	621	2,514	16.1%	24.7%	4.1%	16.6%
Duct Sealing	2,759	15,671	344	674	37.8%	51.1%	2.2%	4.3%
Heat Pump	4,611	15,564	2,730	6,412	3.6%	42.6%	17.5%	41.2%
Other Recorded Measures								
Floor Insulation	2	11,967	-2,177	195	-174.8%	-1116.8%	-18.2%	1.6%
Solar Screen	19	11,604	-639	309	-168.3%	-206.5%	-5.5%	2.7%
Wall Insulation	107	13,637	1,232	1,153	48.0%	106.8%	9.0%	8.5%
Window	47	14,023	-171	591	-553.4%	-28.9%	-1.2%	4.2%
Window AC	1	14,157	3,322	613	15.8%	541.8%	23.5%	4.3%

Table 111. Measure-Level Fixed-Effect Model Results, Residential Standard Offer Program

RSOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	3,579	19,654	2,194	2,961	5.5%	74.1%	11.2%	15.1%
Air Infiltration	6,306	12,961	-94	1,363	99.9%	-6.9%	-0.7%	10.5%
Ceiling Insulation	1,778	15,977	622	3,552	24.1%	17.5%	3.9%	22.2%
Duct Sealing	1,970	15,466	243	668	65.5%	36.4%	1.6%	4.3%
Heat Pump	2,496	19,145	3,193	7,078	4.7%	45.1%	16.7%	37.0%
Other Recorded Measures								
Solar Screen	2	13,033	3,180	136	125.4%	2,333.9%	24.4%	1.0%
Wall Insulation	3	14,697	-3,228	689	196.0%	-468.8%	-22.0%	4.7%
Window	19	15,037	-1,245	813	101.2%	-153.1%	-8.3%	5.4%

Table 112. Measure-Level Fixed-Effect Model Results, Hard-To-Reach Standard Offer Program

HTR SOP	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	17	13,427	2,191	1,345	57.6%	162.9%	16.3%	10.0%
Air Infiltration	4,445	13,474	236	1,328	41.9%	17.8%	1.8%	9.9%
Ceiling Insulation	2,222	14,830	582	1,889	22.1%	30.8%	3.9%	12.7%
Duct Sealing	775	16,146	578	695	37.6%	83.1%	3.6%	4.3%
Heat Pump	659	12,763	2,589	6,134	7.5%	42.2%	20.3%	48.1%
Other Recorded Measures								
Floor Insulation	1	7,512	-3,245	195	4.1%	-1,664.9%	-43.2%	2.6%
Solar Screen	2	12,002	600	166	194.9%	361.0%	5.0%	1.4%
Wall Insulation	7	11,256	555	954	456.6%	58.2%	4.9%	8.5%
Window	5	5,322	-707	383	79.1%	-184.7%	-13.3%	7.2%

Table 113. Measure-Level Fixed-Effect Model Results, Low-Income

LI	n	PRENAC	Model Savings	TRM	Precision	Savings Compared to TRM	Savings as a Percentage of Pre	TRM as a Percentage of Pre
AC	10	11,595	1,779	2,211	51.0%	80.5%	15.3%	19.1%
Air Infiltration	173	14,130	-24	613	-2,196.9%	-3.9%	-0.2%	4.3%
Ceiling Insulation	300	13,231	845	1,083	48.0%	78.0%	6.4%	8.2%
Duct Sealing	21	17,578	418	460	305.1%	90.8%	2.4%	2.6%
Heat Pump	1,467	10,681	1,895	5,386	10.5%	35.2%	17.7%	50.4%
Other Recorded Measures								
Floor Insulation	1	16,421	157	237	285.9%	66.2%	1.0%	1.4%
Solar Screen	15	11,360	-1,533	352	-94.4%	-435.9%	-13.5%	3.1%
Wall Insulation	97	13,776	1,014	1,182	62.7%	85.8%	7.4%	8.6%
Window	28	13,336	411	440	322.9%	93.4%	3.1%	3.3%
Window AC	1	14,157	2,701	613	20.5%	440.4%	19.1%	4.3%

Table 114. Comparison of Individual Household Weather-Normalized Model with Measure-Level Fixed-Effect Model, Overall

Overall	n	Individual Household Model Savings	Measure-Level Fixed-Effect Model Savings	Difference	Percentage Difference
AC	3,605	2,235	2,237	2	0.1%
Air Infiltration	10,898	31	22	8	26.9%
Ceiling Insulation	4,267	651	621	30	4.6%
Duct Sealing	2,759	387	344	42	11.0%
Heat Pump	4,611	2,728	2,730	2	0.1%
Other Recorded Measures					
Floor Insulation	2	-1,340	-2,177	837	-62.4%
Solar Screen	19	-686	-639	47	-6.9%
Wall Insulation	107	1,319	1,232	88	6.7%
Window	47	-8	-171	163	-2124.3%
Window AC	1	2,790	3,322	533	19.1%

Table 115. Comparison of Individual Household Weather-Normalized Model with Measure-Level Fixed-Effect Model, Residential Standard Offer Program

RSOP	n	Individual Household Model Savings	Measure Level Fixed-Effect Model Savings	Difference	Percentage Difference
AC	3,579	2,229	2,194	35	1.6%
Air Infiltration	6,306	-62	-94	32	-51.6%
Ceiling Insulation	1,778	615	622	6	1.0%
Duct Sealing	1,970	383	243	140	36.5%
Heat Pump	2,496	3,160	3,193	34	1.1%
Other Recorded Measures					
Solar Screen	2	3,306	3,180	126	3.8%
Wall Insulation	3	-3,133	-3,228	95	-3.0%
Window	19	-1,411	-1,245	166	-11.8%

Table 116. Comparison of Individual Household Weather-Normalized Model with Measure-Level Fixed-Effect Model, Hard-To-Reach Standard Offer Program

HTR SOP	n	Individual Household Model Savings	Measure Level Fixed-Effect Model Savings	Difference	Percentage Difference
AC	17	2,070	2,191	121	5.8%
Air Infiltration	4,445	179	236	58	32.2%
Ceiling Insulation	2,222	617	582	35	5.7%
Duct Sealing	775	471	578	107	22.7%
Heat Pump	659	2,653	2,589	64	2.4%
Other Recorded Measures					
Floor Insulation	1	-3,336	-3,245	91	-2.7%
Solar Screen	2	565	600	34	6.1%
Wall Insulation	7	419	555	136	32.4%
Window	5	-1,554	-707	847	-54.5%

Table 117. Comparison of Individual Household Weather-Normalized Model with Measure-Level Fixed-Effect Model, Low-Income

LI	n	Individual Household Model Savings	Measure Level Fixed-Effect Model Savings	Difference	Percentage Difference
AC	10	1,872	1,779	93	5.0%
Air Infiltration	173	113	-24	136	121.2%
Ceiling Insulation	300	950	845	106	11.1%
Duct Sealing	21	621	418	204	32.8%
Heat Pump	1,467	1,868	1,895	27	1.5%
Other Recorded Measures					
Floor Insulation	1	1,147	157	991	86.3%
Solar Screen	15	-1,542	-1,533	10	-0.6%
Wall Insulation	97	1,218	1,014	205	16.8%
Window	28	702	411	291	41.5%
Window AC	1	2,371	2,701	330	13.9%

Individual Household Weather-Normalization Demand Models:

To estimate demand impacts, the same model and coefficients from our *individual household weather-normalization* models are used. The key difference between this model and the *individual household weather-normalization* models is that rather than fitting the whole year of TMY3 data to the model coefficients in the pre- and post-period, only the top 20 hours, as defined by the TRM, are fit to the model coefficients, which results in an hourly demand estimate for the top 20 hours in winter and summer for the pre- and post-periods.

Once we have the hourly demand estimates for the pre- and post-period for the top 20 hours for that account's climate zone, we multiply the peak demand probability factor (PDPF) provided by the TRM for each hour by the demand estimate produced by our model coefficients. Next, we sum the term we just calculated and divide by the sum of the PDPF. This process is repeated for both the pre- and post-period, providing an estimate of peak demand in the pre-period and the post-period. We finally subtract the post-estimate from the pre-estimate, with the difference being our reduction in peak demand for that account.

Finally, to come to the reported numbers, we take the mean of the difference between the pre- and post-estimates for accounts in different programs. We do this for the treatment and comparison group, and subtract out the change in the comparison group, just as we have done in calculating our other results. When looking at the measure level, we re-use the regression noted towards the bottom of the Individual Household Weather Normalization Models section (**Equation 2**) but replace the change in normalized annual consumption with the change in peak demand. Both of these methods result in an adjusted peak demand reduction for the segment of interest. Complete peak demand results are available in the report.

TECHNICAL APPENDIX 2 NEW HOMES CONSUMPTION ANALYSIS

Methodology

The EM&V team performed a consumption analysis of the new homes programs to evaluate energy and demand impacts. The results are based on usage data that was weather normalized using an iterative method to optimize heating and cooling setpoints for each account.

The primary goal was to evaluate how well the TRM-based savings estimates characterized reductions in electric consumption in participating homes. We compared average annual energy usage estimated using the TRM methodology with the average weather-normalized usage observed in participating meters' data.

In addition to the energy model analysis, a secondary analysis compared the program homes with non-participating homes to provide broader context about real-world energy consumption in the markets in which the programs operate. Using this comparison group, we also estimated peak demand savings using a modified version of the approach presented in the TRM. Ultimately, because the comparison group sample had data limitations regarding household characteristics, the EM&V team provided numeric results, but emphasizes the broader suggested market transformation trends.

Data Sources

The EM&V team used the following data sources to perform the consumption analysis:

- **Program tracking data** for the new homes programs, provided by the Texas utilities for all electric participants from January 2017 through December 2018. These data included unique account numbers, participation dates, addresses, participant identifiers, and total reported TRM savings estimates per participant. These data also included detailed measure information such as measure names, reported Texas TRM savings estimates for each measure received, household characteristics, and the utility associated with the account.
- **Consumption data** for new homes, provided by the Texas utilities, for all electric use measured in 15-minute-intervals through advanced metering infrastructure meters. These data included time signatures for each interval reading and all kWh consumption, by participant account, from January 2017 (or when the meter entered service after that date) through December 2019.
- **Texas weather data**, retrieved from the ASOS network.[27] These data contained the hourly temperature readings for January 1, 2017, to January 1, 2020. We used data from the station closest to each TMY3 station, for a total of 59 weather stations. For more information on the Texas weather data, see Appendix 1-A: Supplemental Information on Weather Data.
- **County property tax data** containing square footage by address for relevant counties. We obtained property tax data for counties that had more than 50 participating new homes with the primary goal of adding square footage data to the non-participant group. These were available as downloads from various county tax and county appraiser

[27] https://mesonet.agron.iastate.edu/request/download.phtml?network=TX_ASOS