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

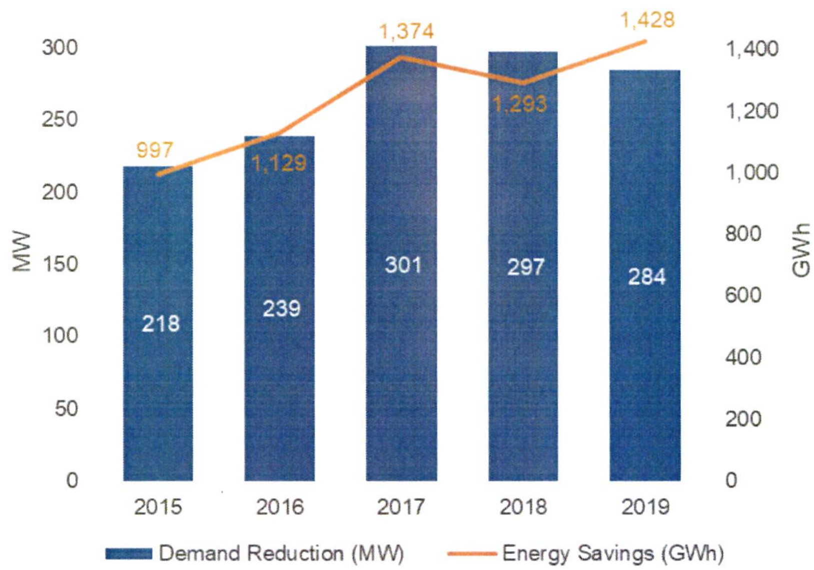
6.1.1 Savings

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.

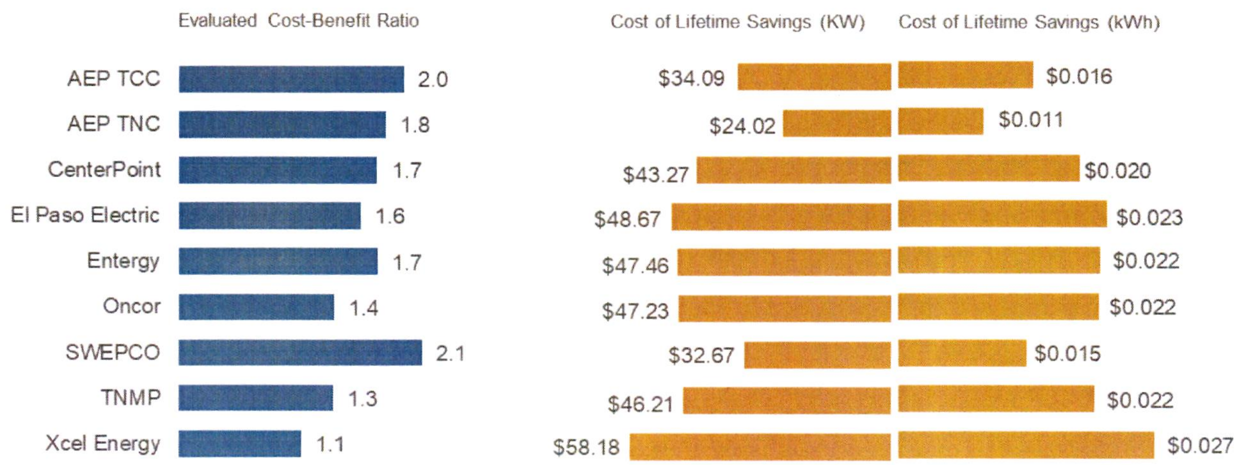
Figure 32. Total Statewide Evaluated Gross Demand Reduction and Energy Savings by Program Year—Load Management Programs



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.

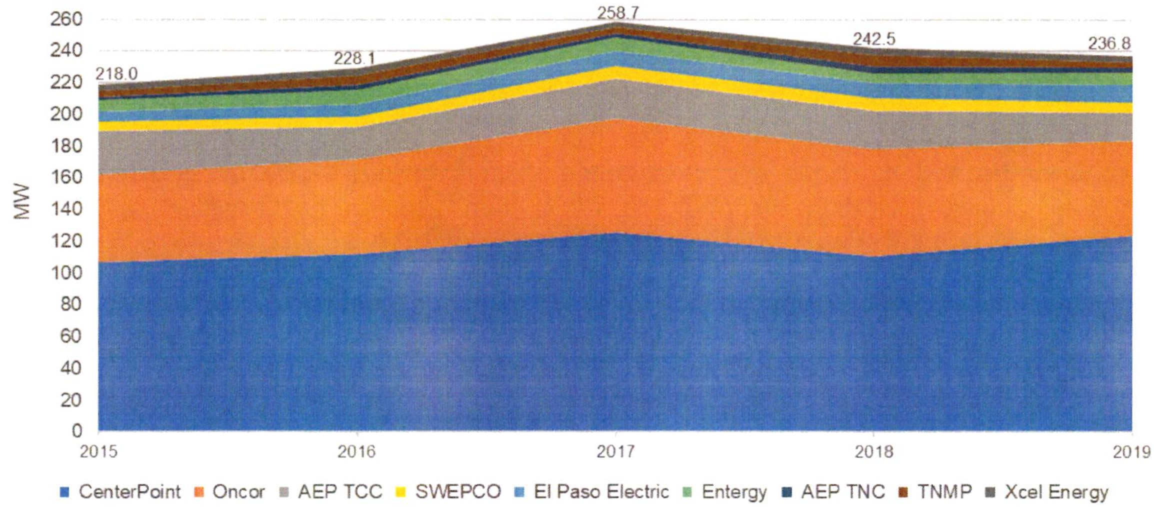
6.2.3 Impact Results

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

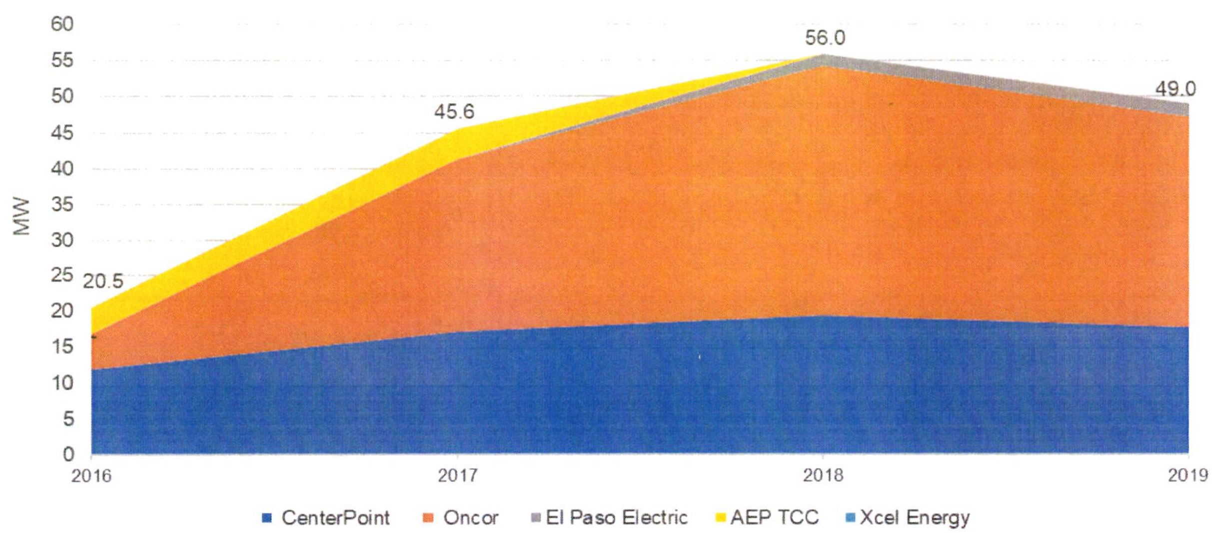
The total evaluated savings for the three programs were:

- 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.[21] 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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[21] 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.

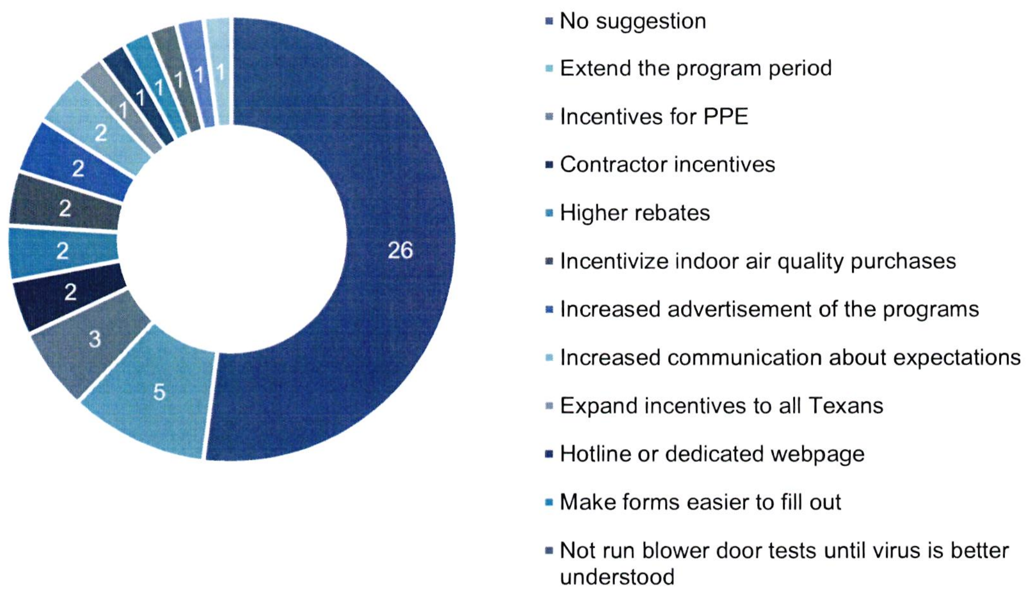
7.2 SERVICE PROVIDER FEEDBACK

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.

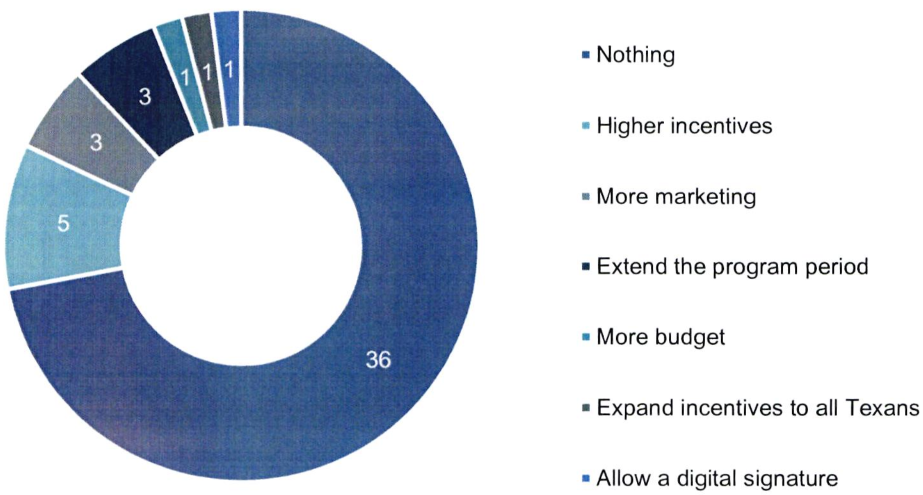
A total of 50 service providers were asked, "What support or program options would you like to see in the Texas utility programs to help your firm continue to implement energy efficiency projects given the current COVID-19 *stay home/work safely* practices?" A little over half of the respondents (26 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[22], 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.

[22] 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.).
	  o Liability is going to be a concern, as even once the *stay at home* orders are lifted, COVID-19 will still be around.
	  o 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.

Utility	COVID-19 Response
Massachusetts Program Administrators (Mass Saves)	• 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. o 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. o 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. o 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. o 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.

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.[23] This data contained the hourly temperature readings for the period between January 1, 2017, to January 1, 2020. We used data from the station

[23] 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.[24] 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.

[24] 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.

<u>Heating Type Findings:</u>

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.

<u>Replacement of Heat Pump Findings:</u>

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%

<u>Replacement of AC Findings:</u>

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%

<u>Peak Demand Findings:</u>

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

			Summer				
Program	**Group**	**n**	**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%
			Winter				
Program	**Group**	**n**	**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	Summer: Model Savings (kW)	Summer: TRM Savings	Summer: Model as percentage of TRM	Summer: 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	Winter: Model Savings (kW)	Winter: TRM Savings	Winter: Model as percentage of TRM	Winter: 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	Summer: Model Savings (kW)	Summer: TRM Savings	Summer: Model as percentage of TRM	Summer: 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	Model Savings (kW)	TRM Savings	Model as percentage of TRM	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	Model Savings (kW)	TRM Savings	Model as percentage of TRM	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	Summer Model Savings (kW)	Summer TRM Savings	Summer Model as percentage of TRM	Summer Savings as percentage of Pre
AC	Treatment	10	3.66	0.81	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	Winter Model Savings (kW)	Winter TRM Savings	Winter Model as percentage of TRM	Winter 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

			Summer				
RSOP	Group	n	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%
			Winter				
RSOP	Group	n	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	Model Savings (kW)	TRM Savings	Model as percentage of TRM	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%
			Winter				
LI	**Group**	**n**	**Peak Pre**	**Model Savings (kW)**	**TRM Savings**	**Model as percentage of TRM**	**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[25] 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:

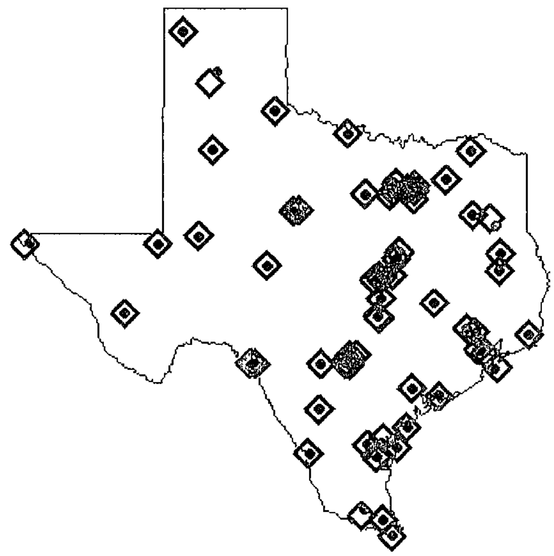
While there are 208 ASOS stations, only 59 were used. The reason for this is that each account (there are 61) would also need to be matched with a TMY3 weather station to complete the weather normalization. A majority of TMY3 and ASOS stations are co-located, and all TMY3 stations are within 20 miles 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.

[25] 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*.[26] 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).[27] 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

[26] 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.

[27] 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.[28] 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.

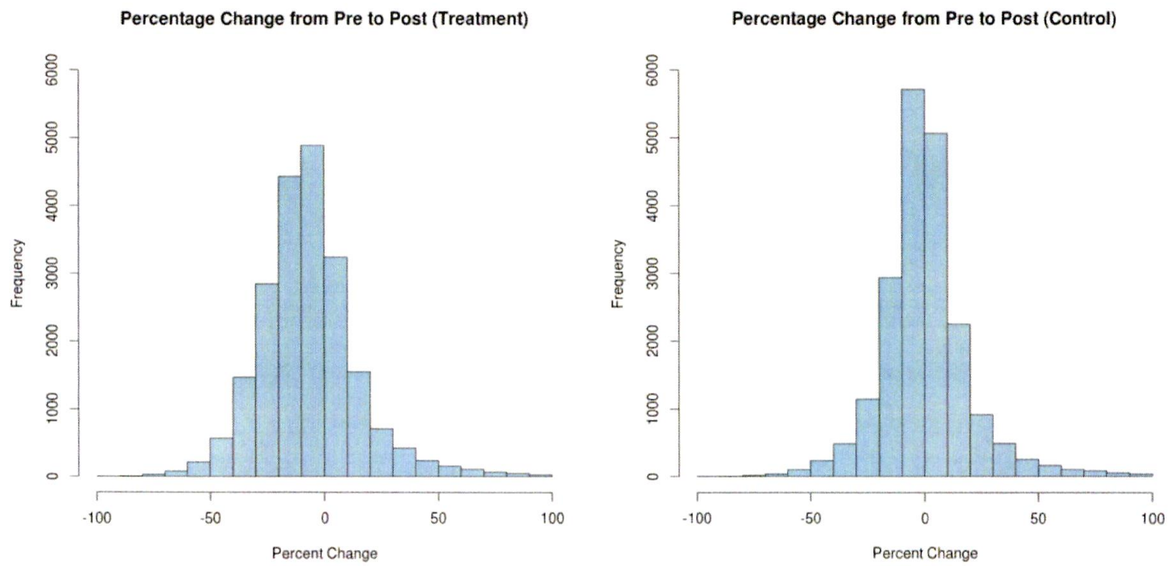
Table 90. Accounts Remaining After Screening Step 7

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

[28] 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.

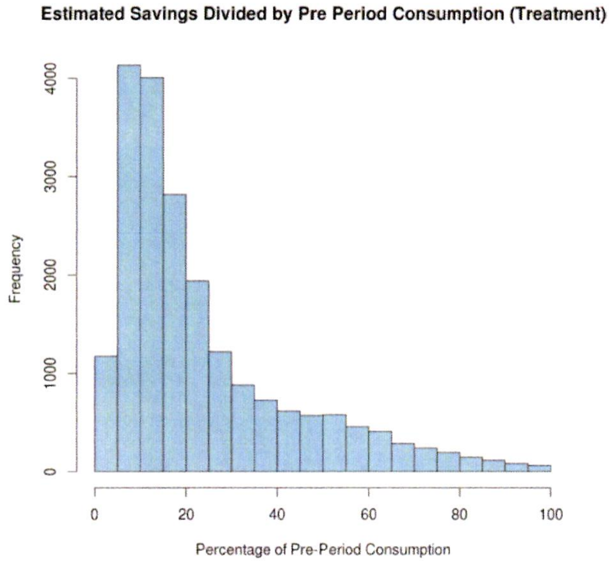
This screening step applies to the treatment group only. The histogram below shows the project size as a percentage of the pre-period consumption for each treatment group household. Table 92 and Table 93 present the results of this screening step.

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



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.

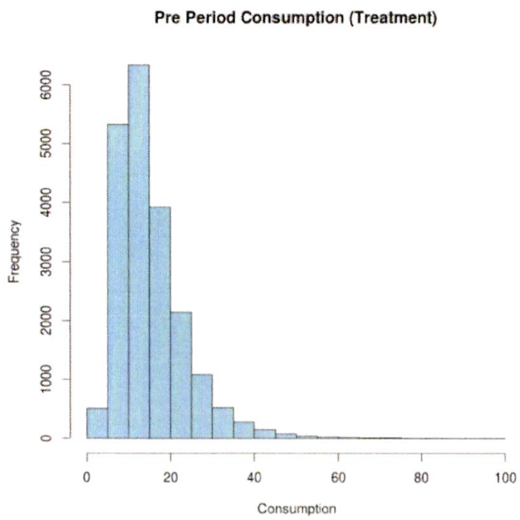
A histogram showing what the distribution looked like before these accounts were removed is shown below for both the pre- and post-period for treatment and comparison groups. To make them readable, a few accounts over 100,000 kWh were removed before plotting the histogram. Table 94 and Table 95 present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

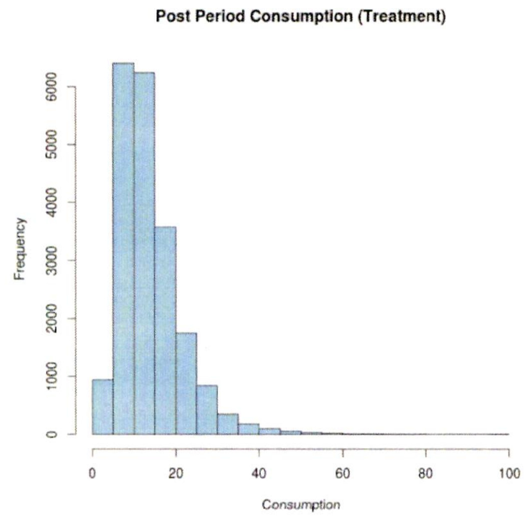
Table 94. Accounts Remaining After Screening Step 9

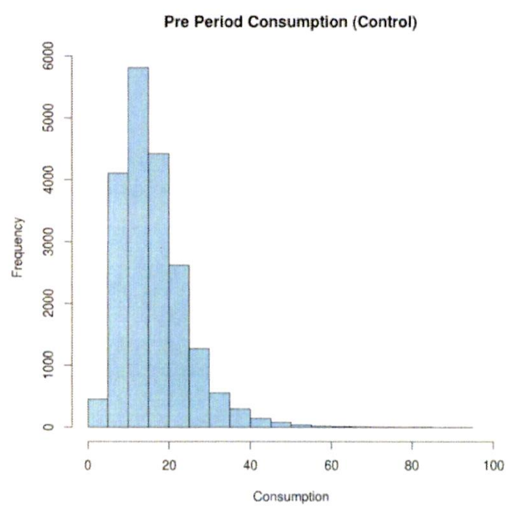
Total kWh	AEP TCC	AEP TNC	CenterPoint	Oncor	TNMP	Total
Treatment	3,415	606	1,308	15,756	1,174	22,259
Comparison	3,475	399	83	14,077	1,362	19,396

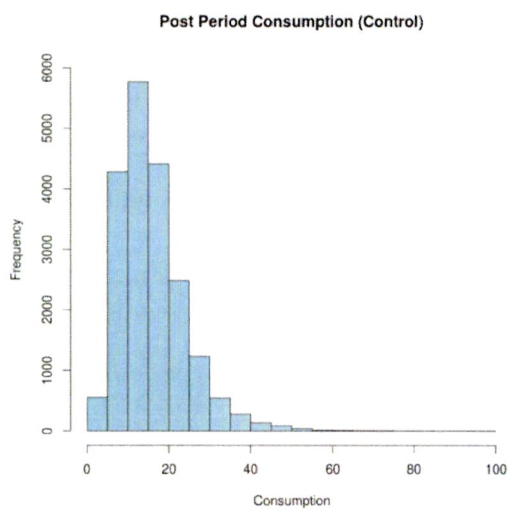
Table 95. Accounts Removed Due to Screening Step 9

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

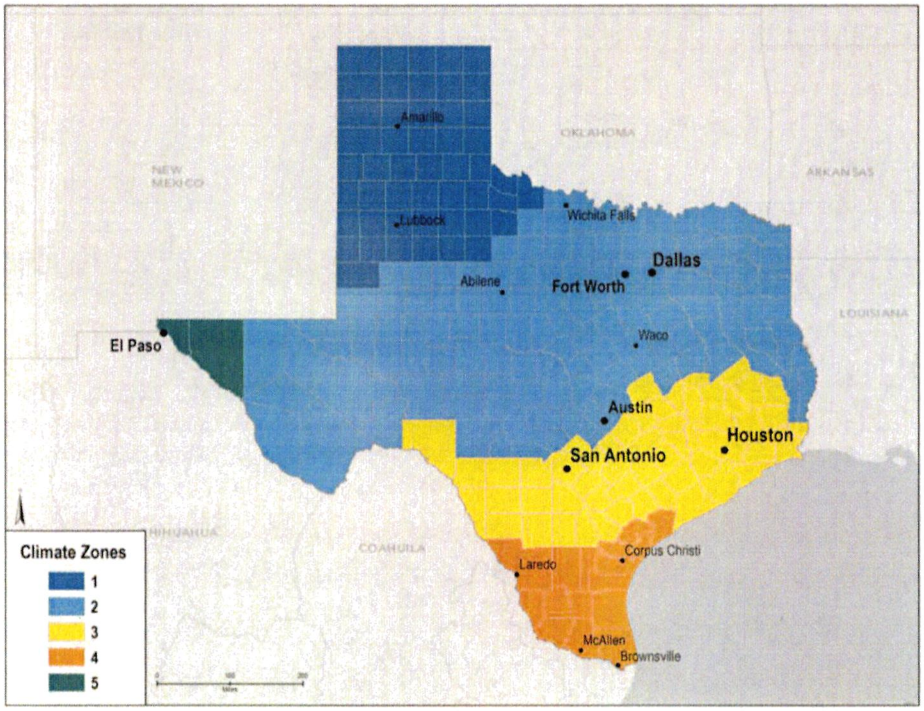


Table 98. Model Screening Steps by Climate Zone, Treatment

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

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

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_ι = 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

$CDH_{\iota t}$ = 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

$Hour\_1_{\iota t}$ = 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		Comparison	
	Number of Accounts	% of Accounts	Number of Accounts	% 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		Comparison	
	Number of Accounts	% of Accounts	Number of Accounts	% 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

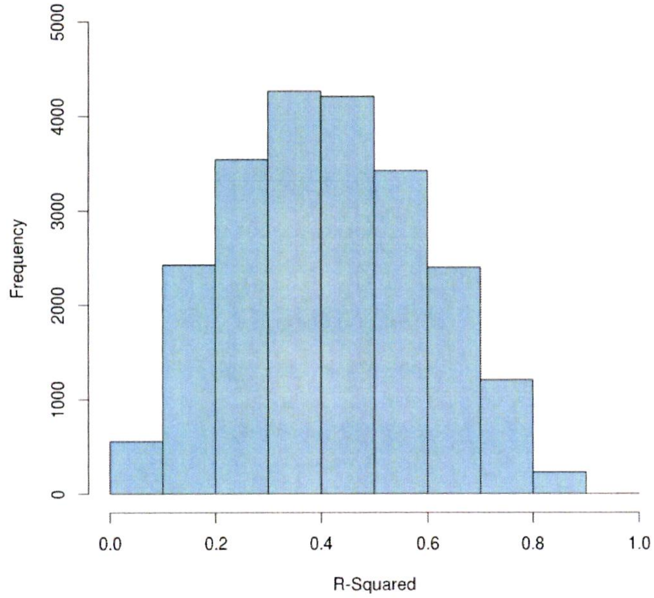


Figure 41. Treatment Group R^2 Distributions, Post-Period

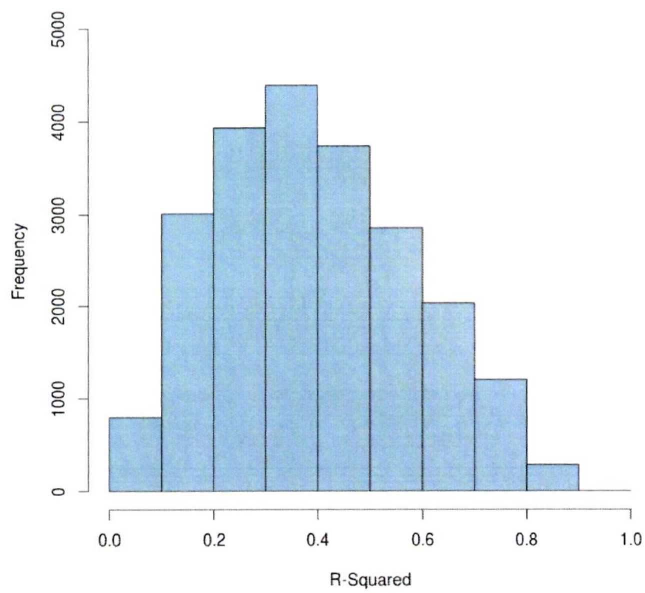


Figure 42. Comparison Group R^2 Distributions, Pre-Period

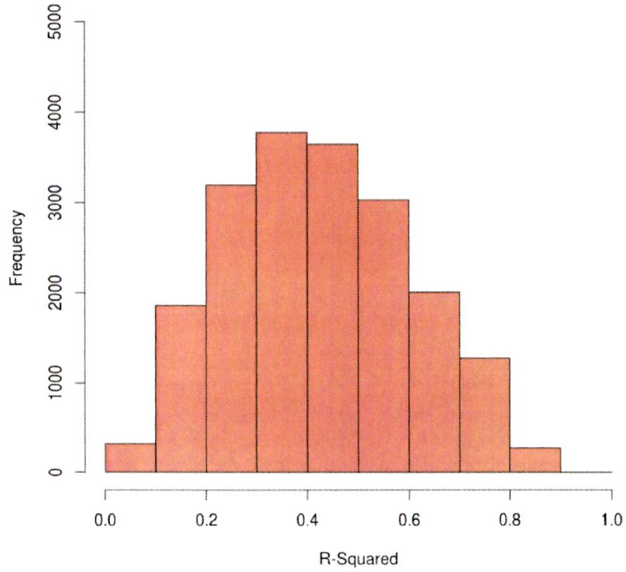
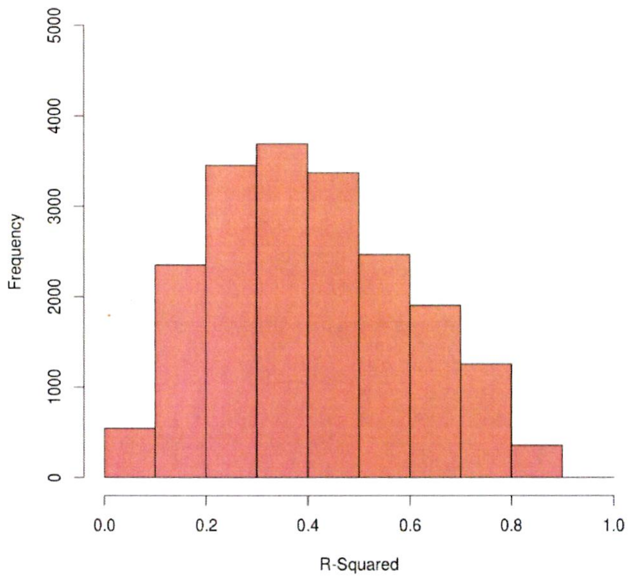


Figure 43. Comparison Group R^2 Distributions, Post-Period



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.[29] 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

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

offices' websites and included Brazoria, Chambers, Fort Bend, Galveston, Harris, Montgomery, Nueces, San Patricio, Waller, and Webb counties.[30]

- **City and town population data** from the US Census Bureau.[31] These data were used to classify new homes by census division and stratify the data into segments representing urbanized areas, urban clusters, and rural areas.

Participant Group

The EM&V team defined the participant group as homes that participated in ERCOT utilities' new homes programs in PY2018. These accounts came from three utility companies: American Electric Power-Texas Central Company (AEP), CenterPoint Energy (CenterPoint), and Texas-New Mexico Power Company (TNMP).

Comparison Group

To analyze the efficiency of homes that did not participate in the program, we used a group of non-program customers with meters that came online in 2017 to late 2018 as the comparison group. These non-participants were selected from the three utility companies with new homes programs to control for differences in code enforcement or building practice across counties. All non-program customers were selected from counties that had at least 50 program participants. Furthermore, only counties with publicly downloadable tax data that contained square footage were used as this data point was an important factor used during the analysis.

Analysis Sample

Data Screening

Using the initial treatment and comparison groups, the EM&V team cleaned the data and screened for several criteria to identify the final analysis samples. The consumption analysis was conducted using participants with 12 full months of consumption data in calendar year 2019. Account-level reviews were performed on all individual households' monthly consumption to identify anomalies (e.g., periods of unoccupied units or missed readings) that could potentially bias results.

The EM&V team used the following screening criteria to remove anomalies, incomplete records, and outlier accounts that could potentially bias savings estimates:

- Accounts that could not be matched between participant program tracking data and consumption data (e.g., missing meter data or tracking data).
- Comparison accounts located in counties without sufficient participant accounts or in counties with inaccessible tax data. The EM&V team determined that non-participant accounts located in counties without sizeable participant populations would not provide appropriate comparisons because of different climate and code-enforcement conditions.
- Accounts that have solar interconnect agreements. Since these accounts produce some or all of their own electricity, we would not have complete consumption data.
- Accounts that recorded their first meter-reading after January 1, 2019, or recorded their last meter reading before December 31, 2019. In other words, accounts that had less

[30] See Appendix E

[31] US Census City and Town Population Total (2010-2019), https://www2.census.gov/programs-surveys/popest/tables/2010-2019/cities/totals/SUB-IP-EST2019-ANNRES-48.xlsx

than one full year of meter readings. Industry-standard practice in consumption analyses is to use one full year of usage data pre- and post-treatment; however, since these are new measures, no pre-treatment data exists.

- Accounts that recorded their first full day of non-zero kWh meter usage after January 1, 2019, which controlled for homes that were unoccupied at the start of the year. Given that the accounts in this analysis are new construction, it is important to consider that they may not be occupied at the start of the measured period, even if meters are installed. Accounts with extended periods of zero meter-usage indicated that base-load appliances were not yet installed. While it is a proxy for occupancy, the EM&V team felt that using the first date with a full day of meter-readings indicated that major appliances had been installed and thus occupancy was plausible.
- Accounts that were missing more than the equivalent of 12 hours total of consumption data (i.e., missing more than 48 15-minute meter data readings across the entire 365 days, not necessarily 48 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. These levels were set at half of the values used in the retrofit analysis because the new homes analysis only uses one year of meter readings.
- Accounts with 15 days (1,440 15-minute meter data readings) of meter readings of zero kWh, in aggregate. 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; therefore, retaining accounts with some zero kWh readings was essential to preserve the size of the analysis group. As with the missing data metric, the threshold here was indexed at half the limit of the retrofit analysis.
- Accounts with total usage that was excessively high or low during the program year (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.
- Comparison accounts with square footage below the participant minimum or greater than the participant maximum (under 784 or over 7,522 square feet). Comparison accounts that were outliers due to household size were deemed unlikely to prove useful for this analysis as they likely had characteristics that differentiated them from the participant population.
- Comparison accounts that were identified as cellular network towers, cable or phone relays, or other types of commercial accounts by the utility companies.

Model Attrition

Following these data screening steps, we retained a matched analytic sample consisting of 13,760 treatment and 17,288 comparison group accounts. Table 118 provides details of the screening process for accounts in the new homes program, and Table 119 provides utility-specific attrition. The data for the program participants tended to have fewer missing data than those found in the comparison group. Most of the participant accounts that were removed were due to excessive numbers of zero kWh readings, indicating potential irregularities in the smart meter function; however, this issue was still more pronounced in the comparison group.

Table 118. New Homes Program Screening - Statewide

	Participant Group		Comparison Group	
Screen	Accounts Remaining	Percentage Remaining	Accounts Remaining	Percentage Remaining
Original electric accounts	14,123	100%	56,150	100%
Did not match to billing data	14,120	100%	56,089	100%
Accounts from irrelevant comparison counties or counties with insufficient data	14,031	99%	46,941	84%
Accounts with solar interconnects	14,000	99%	46,884	83%
Accounts with insufficient start or end dates	13,958	99%	24,154	43%
Accounts that were not occupied at the start of 2019	13,958	99%	23,827	42%
Accounts with excessive missing meter reads	13,912	99%	22,687	40%
Accounts with excessive zero-kWh meter reads	13,763	97%	20,747	37%
Accounts that were usage or square-footage outliers	13,760	97%	18,264	33%
Accounts that were identified as commercial	13,760	97%	17,288	31%
Final Analysis Group	**13,760**	**97%**	**17,288**	**31%**

Table 119. New Homes Program Screening - Utility

Participant Group	AEP	CenterPoint	TNMP
Original Accounts	743	12,769	611
Final Accounts	592	12,569	599
Percentage Retained	**80%**	**98%**	**98%**
Comparison Group			
Original Accounts	10,436	43,169	2,545
Final Accounts	1,342	15,150	796
Percentage Retained	**13%**	**35%**	**31%**

Comparison meters had many reasons that contributed to a retention rate of approximately 33 percent. Most of the account loss stemmed from the original comparison account population having less selective criteria than the participants and can be attributed to specific data cleaning steps.

AEP and TNMP both provided many accounts that were in counties scattered throughout the state of Texas that did not correspond with where participant accounts were located. These accounts were in different counties and the code enforcement, market conditions, and building practices would likely differ and thus would not provide a relevant comparison. As a result, they are unlikely to make useful comparisons for the participant accounts. Additionally, some of the counties that had sizeable populations did not have any publicly downloadable databases that included square footage, so these were dropped from the comparison group. CenterPoint had many accounts that started after January 1, 2019, and thus were missing a full twelve months of data, which lead to a loss of almost half of their comparison accounts. While we attempted to screen ineligible accounts prior to requesting meter data, CenterPoint identified a group of approximately 1,000 comparison accounts that were commercial customers, and thus were removed from this analysis. CenterPoint also identified a group of accounts that were potentially multi-unit households, however due to the difficulty differentiating between true multi-unit buildings and single-family homes built close together, these were ultimately kept in the analysis. All the utilities suffered from issues with missing and zero kWh readings, which lead to further attrition that ultimately resulted in the relatively low retention rate.

Modeling Approach

Household-level weather normalization models

The team ran account-level regression models with weather-normalized hourly consumption to estimate the effect of weather on each household's energy consumption[32]. Results were then averaged across the sample to determine utility, census division, heating type, and statewide program findings. We originally calculated normalization models using both hourly and daily electricity usage aggregation; however, ultimately decided to use hourly normalization models as they fit the data more accurately.

- For the energy model analysis, treatment accounts were weather-normalized, and their usage was compared to the TRM usage estimates.

[32] For further details, see Appendix C.

- For the comparison analysis, both treatment accounts and comparison accounts were weather-normalized, and the two groups were compared.

Savings Calculation

The EM&V team derived gross energy consumption for the new homes programs using the following equation to compare the evaluated participant savings with those projected by the energy models defined in the TRM. The *plug load* variable used in the formula below represents the percentage of electrical consumption attributable to discretionary electrical consumption. The TRM estimates only include major appliances and heating and cooling; to compare meter data with the TRM estimates, we must include a correction for plug load.

$$Adj. Gross\ Consumption = (Normalized\ Usage_{Participant})(1 - plug\ load)$$

$$Consumption\ Difference = (Adj. Gross\ Consumption) - (TRM\ Modeled\ Consumption)$$

For the comparison analysis, the EM&V team derived adjusted gross energy savings for the new homes programs compared to the comparison group using the formula below. This analysis represents the effect the new homes programs have on household consumption independent of standard building practices in their respective markets. These calculations do not include adjustments for plug load under the assumption that participant and comparison households use similar amounts of energy as plug load.

$$Adj. Gross\ Savings = Normalized\ Annual\ Usage_{Comparison} - Normalized\ Annual\ Usage_{Participant}$$

Similarly, we calculated peak energy reductions between the participant and comparison groups. We identified the normalized peak energy usage based on the *top 20 hours* methodology defined in the TRM.

$$Adj. Gross\ Peak\ Reduction = Normalized\ Peak\ Usage_{Comparison} - Normalized\ Peak\ Usage_{Participant}$$

Findings: Energy Models

Overall Results

This section presents evaluated savings estimates for the new homes programs at the statewide level, as well as by census division and heating type.

The EM&V team included weather-normalized annual consumption in these results to characterize the average energy consumption of the participant group; this helps control for variation in the temperatures during the program year that may have differed from conditions in a typical year in the same location.

After calculating weather-normalized consumption, usage was compared to the planning estimates reported in the utility tracking databases that are required to be consistent with the statewide TRM (which values are referred to as *TRM* in the tables below). It is important to note that there are differences in the methods used to calculate the evaluated estimates here and those methods used to estimate savings through the TRM. Specifically:

- ***Baseload Consumption*** – Billing analysis includes all electrical consumption during the program period, including the associated discretionary plug load. The TRMs are typically designed to estimate usage based on heating and cooling projections and consumption associated with major installed appliances that such as refrigerators, laundry machines, etc. Because plug load is not included in the TRM estimate, we must account for it before we can compare the two values and estimate it as 15 percent of overall consumption based on existing research[33].

- ***Weather*** – There may be some slight distinctions in weather data that may result in minor differences. As noted, this study uses data from 59 ASOS stations, specifically located nearest to each household in the analysis. However, the TRM primarily uses seven to nine regional stations to more broadly cover the state.

Statewide Findings

Table 120 provides model savings compared to TRM values by census classification and statewide.[34] The TRM is only meant to be accurate at a statewide level. However, we acknowledge there are differences in utilities' service areas that might affect the performance of homes, and one of these differences is the jurisdictions where the homes are built. Local jurisdictions are responsible for code enforcement, and the size of jurisdiction might affect that enforcement.

The US Census Bureau delineates geographic areas based on their population. It classifies areas with more than 50,000 people as *urbanized areas*, areas with between 2,500 and 50,000 as *urban clusters*, and all other areas as *rural*. While we present these additional findings by census division groups here, our focus will continue to be on the overall statewide results.

Statewide, the consumption model average savings converged closely with the TRM estimated savings. The EM&V team feels that the differences in average participant savings between the consumption model and the TRM could very plausibly be attributed to the limitations of estimating discretionary plug load.

Table 120. Census Division and Statewide Savings Summary

Census Division	n	Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference	
		Reference	Model	TRM	Model	TRM		Model	TRM
Urbanized Area	3,970	11,843	9,833	10,262	2,010	1,581	127%	17%	13%
Urban Cluster	9,014	12,177	10,468	10,461	1,709	1,716	100%	14%	14%
Rural Area	776	11,730	11,105	10,097	625	1,633	36%	5%	14%
All	**13,760**	**12,055**	**10,321**	**10,383**	**1,735**	**1,672**	**104%**	**14%**	**14%**

At the census division level, the models performed differently across the stratifications. Overall, results were in line with TRM estimates; however, in urbanized areas, the results indicated that the TRM might be underestimating savings compared to modeled usage (13 percent compared

[33] https://www.esource.com/es-wp-14/mind-gap-taking-comprehensive-look-plug-load-energy-use

[34] See Appendix F for similar results tables with confidence intervals.

to 17 percent). In rural areas, the TRM appears to be overestimating savings (14 percent compared to 5 percent).

Utility Findings

Table 121 provides model savings compared to TRM values by participating utility. Three utility programs participated in the new homes programs and used smart meters to measure usage: AEP, CenterPoint, and TNMP.

At the utility level, results varied widely. CenterPoint had, by far, the largest number of accounts and yielded the most similar results to the TRM estimate. The high number of accounts would suggest that the results are robust, and the models are performing well with a large population. Table 5 summarizes the results of utility savings.

Table 121. Utility Savings Summary

		Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference	
Utility	n	Reference	Model	TRM	Model	TRM		Model	TRM
AEP TCC	592	13,325	11,196	11,803	2,129	1,522	140%	16%	11%
Center Point	12,569	12,009	10,244	10,344	1,765	1,666	106%	15%	14%
TNMP	599	11,770	11,056	9,804	714	1,966	36%	6%	17%

AEP and TNMP both had results that were significantly different from the TRM estimates. The consumption model yielded higher savings for AEP than the TRM predicted (140 percent of TRM savings), while TNMP yielded lower savings (36 percent of TRM savings). The variation in these two utilities' results could potentially be the result of much smaller population sizes compared to CenterPoint, and it is possible that with additional participants, their results would converge on a point closer to the TRM estimates.

Heating Type Findings

Table 122 provides savings compared to TRM values by household space heating technology. Most of the accounts in this sample used natural gas (92 percent), while electric heat pumps (5 percent) and electric resistance (2 percent) made up the remainder.

As with the results overall, we expect to see some natural variation in this comparison due to plug load assumptions. For natural gas accounts, the differences between the calculated savings and TRM estimates were minuscule, echoing the previous finding that the TRM is performing well for homes using natural gas, which constitute the majority of homes in the program.

Table 122. Heating Type Savings Summary

Heating Type	n	Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference	
		Reference	Model	TRM	Model	TRM		Model	TRM
Electric Resistance	329	13,760	12,053	12,769	1,707	991	199%	12%	7%
Heat Pump	706	15,720	11,748	13,534	3,972	2,186	182%	25%	14%
Natural Gas	12,725	11,808	10,197.	10,146	1,611	1,662	97%	14%	14%

The TRM estimates performed less well with the electric heating types, whose modeled usage both varied from the TRM estimates. In both cases, the model estimated average savings much higher than the TRM estimates. Accounts with electric resistance heating yielded average savings similar to households with natural gas, but nearly double what the TRM had predicted. For accounts with heat pumps, average savings were both substantially higher than the TRM estimates and far higher than other accounts overall.

Findings: Comparison Models

Overall Results

This section presents evaluated savings estimates for the new homes programs at the statewide level and census division, as well as by utility and heating type.

The EM&V team included the same weather-normalized annual consumption in these results to characterize the average energy consumption of the participant group, but also followed a similar procedure to normalize the average energy consumption for the comparison group. This weather-normalization helps control for variation in the temperatures during the program year that may have differed from conditions in a typical year in the same location.

Overall, the results of the comparison analysis indicate that the participant accounts are not using less energy than the comparison group. The EM&V team hypothesizes that this is likely due to market transformation stemming from a combination of market forces, including the new homes programs and outside influences.

The EM&V team took steps to ensure that the comparison group shared similar characteristics with the participant group; however, ultimately, it is difficult to be confident that the group provides an accurate analog. Additional information about the comparison group, including additional building or household characteristics, might allow for more accurate analyses in the future.

Statewide Findings

Table 123 provides modeled consumption both for the participant and comparison groups by census division and statewide.[35] At a statewide level, participating homes used slightly less energy than comparison homes on an annual basis.

When considering the weather-normalized energy consumption between the participant and comparison groups, we identified that the comparison households tended to be systematically smaller than the participant households. Since household square footage is related to electricity

[35] See Appendix F for similar results tables with confidence intervals.

associated with heating and cooling, this discrepancy causes the participants to use more electricity overall. To account for these differences, we also calculated the energy intensity of square footage by dividing household annual consumption by square footage for both the participant and comparison groups and then multiplied that by the category average square footage. Table 124 shows the results of this square footage adjusted consumption.

Table 123. Census Division and Statewide Consumption Summary

Census Division	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group
Urbanized Area	Participant	3,970	9,928	643	6%
	Comparison	8,023	10,572		
Urban Cluster	Participant	9,014	10,486	-410	-4%
	Comparison	8,151	10,075		
Rural Area	Participant	776	11,101	-38	0%
	Comparison	1,144	11,064		
All	**Participant**	**13,760**	**10,348**	**21**	**0%**
	Comparison	**17,288**	**10,369**		

Table 124. Census Division and Statewide Consumption Summary (Square Footage Adjusted)

Census Division	Group	n	Group Average Sq. Ft.	Model Average Energy Intensity (kWh/Sq. Ft.)	Census Division Average Sq. Ft.	Sq. Ft. Adjusted Average Consumption	Participant Savings versus Comparison	Participant Savings as a Percentage of Comparison Group
Urbanized Area	Participant	3,970	2,506	4.8	2,444	10,050	596	6%
	Comparison	8,023	2,397	5.1		10,646		
Urban Cluster	Participant	9,014	2,757	4.5	2,622	10,138	540	5%
	Comparison	8,151	2,421	4.8		10,678		
Rural Area	Participant	776	2,725	4.8	2,571	10,493	763	7%
	Comparison	1,144	2,369	5.2		11,255		
All	**Participant**	**13,760**	**2,680**	**4.6**	**2,553**	**10,091**	**673**	**6%**
	Comparison	**17,288**	**2,408**	**5.0**		**10,764**		

When we account for the differences in square footage between groups, the models yield energy savings for participants. However, compared with the Energy Models analysis results (14 percent savings over reference), the comparison group analysis suggests that savings above-market practices are less than 50 percent of the gross savings estimated by the TRM.

As indicated previously, market transformation is one possible explanation for this reduction in savings. If the industry standard has changed to build more energy-efficient housing, the TRM is not designed to represent this phenomenon when estimating energy consumption. If that is the case, it would explain why the energy model analyses appear to be performing well (the TRM is accurately estimating consumption in the participant group), but the comparison models show diminished savings.

Utility Findings

Table 125 and Table 126 provide modeled consumption for both participants and the comparison group, which are broken down by utility using the same methodology as in the previous section. Notably, TNMP shows savings higher than the TRM estimated savings when accounting for square footage.

As with the state and region level, initially, the results here indicated little to no savings across the utilities. When we account for square footage, we see considerable savings associated only with TNMP. One likely explanation for this discrepancy is that TNMP had a much larger difference in average square footage between its participants (2,725 square feet) and its comparison group (2,000 square feet) compared with AEP (1,977 square feet and 1,996 square feet, respectively) and CenterPoint (2,721 square feet and 2,450 square feet, respectively).

Table 125. Utility Consumption Summary

Utility	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group
AEP TCC	Participant	592	11,097	219	2%
	Comparison	1,342	11,316		
CenterPoint	Participant	12,569	10,244	33	0%
	Comparison	15,150	10,278		
TNMP	Participant	599	11,053	-534	-5%
	Comparison	796	10,520		

Table 126. Utility Consumption Summary (Square Footage Adjusted)

Utility	Group	n	Group Average Sq. Ft.	Model Average Energy Intensity (kWh/Sq. Ft.)	Utility Average Sq. Ft	Sq. Ft. Adjusted Average Consumption	Participant Savings versus Comparison	Participant Savings as a Percentage of Comparison Group
AEP TCC	Participant	592	1,977	6.8	1,985	11,428	301	3%
	Comparison	1,342	1,996	7.0		11,728		
Center Point	Participant	12,569	2,721	4.5	2,594	9,917	627	6%
	Comparison	15,150	2,450	4.8		10,543		
TNMP	Participant	599	2,725	5.0	2,411	10,211	2,936	22%
	Comparison	796	2,000	6.4		13,147		

As mentioned above, the results for TNMP show savings higher than the TRM estimates. These higher savings results might be a limitation of the square footage adjustment methodology. However, this might also reflect market practices within TNMP's service area, such as a lag in code adoption or enforcement or at least building practices closer to the code baseline. These results are based on the smallest number of observations for any of the utilities.

Heating Type Findings

The last stratification technique that the EM&V team was interested in was examining the results by heating technology. This stratification presented a unique challenge because, unlike the participant group, there was no heating information provided for the comparison accounts. To overcome this problem, we utilized a train-test split and cross-validation using the participant accounts to develop a model that would predict the heating type in the comparison group based on usage patterns[36].

While this model proved effective in testing and correctly identifying gas accounts, it could not reliably and consistently differentiate between accounts with electric resistance and heat pumps. Because of these limitations, for the comparison analysis, we ultimately decided to group electric heating types and compare them to gas heating.

Table 127 and Table 128 provide modeled consumption for participants and the comparison group stratified by heating fuel (or predicted heating fuel) using the same methodology as in the previous section.

The initial results by heating type yielded similar findings to the other analyses described previously. Without accounting for square footage, the models indicate higher usage for participant homes than comparison homes. Once we adjust for average square footage, we see savings that are larger than in previous stratifications, but still considerably less than the energy models predicted.

Table 127. Heating Type Consumption Summary

Heating Type	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group
Electric Heat	Participant	1,035	11,595	-278	-2%
	Comparison	1,342	11,316		
Natural Gas Heat	Participant	12,725	10,208	82	1%
	Comparison	15,946	10,290		

[36] See Appendix D for further details.

Table 128. Heating Type Consumption Summary (Square Footage Adjusted)

Heating Type	Group	n	Group Average Sq. Ft.	Model Average Energy Intensity (kWh/ Sq. Ft.)	Heating Type Average Sq. Ft	Sq. Ft. Adjusted Average Consumption	Participant Savings versus Comparison	Participant Savings as a Percentage of Comparison Group
Electric Heat	Participant	1,035	2,292	6.8	2,199	11,682	1,310	10%
	Comparison	1,342	1,996	7.0		12,992		
Natural Gas Heat	Participant	12,725	2,717	4.5	2,579	9,861	802	8%
	Comparison	15,946	2,427	4.9		10,663		

Peak Demand Results

As a part of the comparison analysis, the EM&V team also developed a method for calculating peak demand by adapting the method in the TRM, as was laid out in the savings calculation section. The peak demand savings estimates for the new homes programs overall are presented below in Table 129.

It is important to note that winter peak demand is typically only calculated for homes that use electric heating. Based on the tracking data, the EM&V team already knew that most of the participants' accounts use natural gas for heating. However, because the heating fuel is unknown for the comparison group, we again used predicted heat type to present results stratified by heating fuel. The results of this second calculation for the winter peak season are shown in Table 130.

Overall, the results of the peak demand calculation were consistent with the energy portion of the comparison group analysis in that it does not appear that participants reduced demand versus the comparison group. While there initially appeared to be a reduction in winter peak consumption, once heating type was disaggregated, these apparent savings could be attributed to natural gas heated accounts. Winter peak is only calculated for homes with electric heat, and those accounts did not yield savings.

Table 129. Peak Demand Summary

Season	Participant Peak Demand	Comparison Peak Demand	Demand Reduction	Demand Reduction as a Percentage of Comparison Peak
Summer	3.93	3.75	-0.17	-5%
Winter	1.05	1.76	0.71	40%

Table 130. Winter Peak Demand Summary by Heating Type

Season	Heating Type	Participant Peak Demand	Comparison Peak Demand	Demand Reduction	Demand Reduction as a Percentage of Comparison Peak
Winter	Electric Heat	3.23	3.20	-0.02	-1%
	Natural Gas Heat	0.87	1.64	0.77	47%

While the TRM does not provide a method for calculating peak demand reductions in natural gas heated homes, the observed savings are a potentially intriguing finding. Hypothetically, electrical consumption in these homes would not be affected by heating in winter, except for the electrical components associated with ventilation. It is possible that when heating and cooling are not factored into consumption, there are features of participant homes that set them apart from the comparison group in terms of energy efficiency.

Since the comparison group homes are smaller on average than participant homes, we also ran an analysis that adjusted peak demand based on average square footage within each group. The results of this calculation for the entire population are shown in Table 131, and results stratified by heating type are in Table 132.

Table 131. Peak Demand Summary (Square Footage Adjusted)

Season	Participant Peak Demand Intensity (kW/sq. ft.)	Comparison Peak Demand Intensity (kW/sq. ft.)	Sq. ft. Adjusted Participant Peak Demand	Sq. ft. Adjusted Comparison Peak Demand	Sq. ft. Adjusted Demand Reduction	Sq. ft. Adjusted Demand Reduction Percentage
Summer	0.0015	0.0016	3.74	3.98	0.23	6%
Winter	0.0004	0.0007	1.00	1.87	0.87	46%

Table 132. Winter Peak Demand Summary by Heating Type (Square Footage Adjusted)

Season	Heating Type	Participant Peak Demand Intensity (kW/sq. ft.)	Comparison Peak Demand Intensity (kW/sq. ft.)	Sq. ft. Adjusted Participant Peak Demand	Sq. ft. Adjusted Comparison Peak Demand	Sq. ft. Adjusted Demand Reduction	Sq. ft. Adjusted Demand Reduction Percentage
Winter	Electric Heat	0.0014	0.0016	3.10	3.53	0.43	12%
	Natural Gas Heat	0.0003	0.0007	0.83	1.74	0.92	52%

As Table 131 illustrates, once we included the adjustment for the different average square footage between groups, the analysis produced very modest demand savings for all accounts during summer peak (6 percent reduction) and slightly more pronounced demand reduction in winter (46 percent reduction).

When heating type is considered, all-electric homes yielded peak demand savings of 12 percent for the winter season. Accounts with natural gas heating showed substantial savings during the winter peak (52 percent). The results overall, as well as by heating type, indicate that peak demand reductions were much higher in the winter compared to summer, both in terms of relative percent of peak demand as well as absolute peak kW.

APPENDIX 2-D: HEAT TYPE PREDICTION DETAILS

The EM&V team utilized a model training and testing approach to predict the heating type in the comparison group. This method entailed randomly splitting the complete participant data set into a training subset (70 percent of the data) and a testing subset (30 percent of the data). Using the consumption and demographic details, we trained a model on the characteristics specific to different heating types. We then used this model to predict the heating type in the test portion of the participant population. Because we knew the heating type of all the participant accounts, we could compare whether the model accurately predicted the heating type in the test group (whose heating type we also knew) to evaluate its accuracy.

This testing process was repeated six times with different random samples of the population to further refine the training model to reduce bias and cross-validate results. After each round, the predictions were compared to actual heating types so that model accuracy could be tested. The accuracy was averaged over the six periods to arrive at approximately 94 percent. Upon examination of the misidentified accounts, nearly all appeared to be either heat pumps or electric resistance. This finding indicated that, while the model appeared capable of distinguishing natural gas versus electric heat, it was not sensitive enough to differentiate different types of electric heat. Due to this limitation, the EM&V team ultimately decided that we were not confident we could separate heat pumps and electric resistance and grouped the electric heating types to minimize identification errors.

Finally, once the model was trained and tested, it was applied to the comparison group to predict the heating type of these accounts based on their consumption and demographic details. The predicted results showed that the sample contained 1,342 electric heating accounts (7.3 percent) and 16,922 natural gas heating accounts (92.7 percent). The predicted results matched the participant group closely, which had 1,035 combined electric heating accounts (7.5 percent) and 12,725 natural gas heating accounts (92.5 percent).

APPENDIX 2-E: COUNTY DATA DETAILS

This appendix describes counties and county tax data relevant to the new homes programs analyses in greater detail. We used county tax data downloads to obtain household square footage for accounts in the comparison group.

One of the characteristics of the raw comparison group data was a much wider dispersal of accounts throughout the state than in the participant group. In order to make the sample distribution as similar as possible to the participant accounts, the decision was made to only include comparison accounts from counties with at least 50 participants. Ten counties met this initial requirement: Brazoria, Chambers, Fort Bend, Galveston, Harris, Montgomery, Nueces, San Patricio, Waller, and Webb.

Seven of these counties (all except Chambers, Waller, and Webb) had publicly available tax record data that could be downloaded and contained household square footage. Chambers county had publicly downloadable data; however, it did not contain square footage. Waller and Webb counties both had searchable databases that allowed individual address searches, but not downloadable data.

Due to the posed limitations, we took an alternative approach to get square footage for homes in these counties. Rather than individually query households one at a time, we instead looked for overlapping records from other neighboring counties; this allowed us to get the square footage data for a small subset of homes in these counties. However, this subset was enough to serve as a comparison in those areas. Table 133 illustrates the final numbers of participant and comparison accounts retained in each of the counties used in this analysis.

Table 133. County Distribution Summary

County Name	Group	n
Brazoria County	Participant	1,070
	Comparison	1,631
Chambers County	Participant	101
	Comparison	293
Fort Bend County	Participant	3,642
	Comparison	3,001
Galveston County	Participant	742
	Comparison	1,138
Harris County	Participant	6,296
	Comparison	10,131
Montgomery County	Participant	1,050
	Comparison	545
Nueces County	Participant	271
	Comparison	676
San Patricio County	Participant	75
	Comparison	154
Waller County	Participant	267
	Comparison	183
Webb County	Participant	246
	Comparison	512

APPENDIX 2-F: RESULTS TABLES WITH CONFIDENCE INTERVALS

This appendix contains similar tables to the results sections, but they have been expanded to include precision levels at the 90 percent confidence interval. These precision values were added and subtracted from the mean to provide the lower and upper bounds of the estimate at 90 percent confidence. The purpose of these tables is to provide additional information about the precision with which we calculated the means used in the primary results section. number of accounts that received the measure as well as the precision of the estimate.

Table 134 through Table 136 provide precision levels for the energy models, while

Table 137 through Table 139 provide precision levels for the comparison analysis. One important note is that as the sample is stratified into groups with fewer accounts, the precision level tends to fall, indicating that the results are less reliable. In these results, it is generally the case that strata with fewer than 1,000 accounts tended to suffer diminished precision.

Table 134. Census Division and Statewide Savings Summary with 90% Confidence Interval

Census Division	n	Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference		Average Model Savings Confidence Interval at 90%		
		Reference	Model	TRM	Model	TRM		Model	TRM	Precision	Lower Bound	Upper Bound
Urbanized Area	3,970	11,843	9,833	10,262	2,010	1,581	127%	17%	13%	4.6%	1,918	2,102
Urban Cluster	9,014	12,177	10,468	10,461	1,709	1,716	100%	14%	14%	3.8%	1,644	1,775
Rural Area	776	11,730	11,105	10,097	625	1,633	36%	5%	14%	39.7%	377	874
All	**13,760**	**12,055**	**10,321**	**10,383**	**1,735**	**1,672**	**104%**	**14%**	**14%**	**3.0%**	**1,682**	**1,787**

Table 135. Utility Savings Summary with 90% Confidence Interval

Utility	n	Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference		Average Model Savings Confidence Interval at 90%		
		Reference	Model	TRM	Model	TRM		Model	TRM	Precision	Lower Bound	Upper Bound
AEP TCC	592	13,325	11,196	11,803	2,129	1,522	140%	16%	11%	10.5%	1,906	2,352
Center Point	12,569	12,009	10,244	10,344	1,765	1,666	106%	15%	14%	3.1%	1,710	1,820
TNMP	599	11,770	11,056	9,804	714	1,966	36%	6%	17%	36.6%	452	975

Table 136. Heating Type Savings Summary with 90% Confidence Interval

Heating Type	n	Average Participant Annual Consumption			Average Participant Savings		Percentage of Savings Compared to TRM	Savings as a Percentage of Reference		Average Model Savings Confidence Interval at 90%		
		Reference	Model	TRM	Model	TRM		Model	TRM	Precision	Lower Bound	Upper Bound
Electric Resistance	329	13,760	12,053	12,769	1,707	991	199%	12%	7%	18.4%	1,393	2,021
Heat Pump	706	15,720	11,748	13,534	3,972	2,186	182%	25%	14%	3.4%	1,557	1,665
Natural Gas	12,725	11,808	10,197	10,146	1,611	1,662	97%	14%	14%	6.0%	3,732	4,212

Table 137. Census Division and Statewide Consumption Summary with 90% Confidence Interval

Census Division	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group	Precision	Lower Bound	Upper Bound
Urbanized Area	Participant	3,970	9,928	644	6%	1.1%	9,822	10,035
	Comparison	8,023	10,572			1.2%	10,443	10,700
Urban Cluster	Participant	9,014	10,486	-441	-4%	0.7%	10,409	10,562
	Comparison	8,151	10,075			1.1%	9,966	10,184
Rural Area	Participant	776	11,101	-37	0%	2.9%	10,782	11,420
	Comparison	1,114	11,064			2.8%	10,753	11,374
All	**Participant**	**13,760**	**10,348**	**21**	**0%**	**0.6%**	**10,286**	**10,410**
	Comparison	**17,288**	**10,369**			**0.8%**	**10,288**	**10,451**

Table 138. Utility Consumption Summary with 90% Confidence Interval

Utility	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group	Precision	Lower Bound	Upper Bound
AEP TCC	Participant	592	11,097	219	2%	2.3%	10,839	11,355
	Comparison	1,342	11,316			2.0%	11,095	11,537
CenterPoint	Participant	12,569	10,244	37	0%	0.6%	10,180	10,309
	Comparison	15,150	10,278			0.9%	10,188	10,367
TNMP	Participant	599	11,053	-534	-5%	2.8%	10,748	11,359
	Comparison	796	10,520			2.5%	10,259	10,780

Table 139. Heating Type Consumption Summary with 90% Confidence Interval

Heating Type	Group	n	Model Average Consumption (kWh)	Participant Savings Versus Comparison	Participant Savings as a Percentage of Comparison Group	Precision	Lower Bound	Upper Bound
Electric Heat	Participant	1,035	11,595	-278	-2%	1.8%	11,388	11,801
	Comparison	1,342	11,316			2.0%	11,095	11,537
Natural Gas Heat	Participant	12,725	10,208	82	1%	0.6%	10,144	10,272
	Comparison	15,946	10,290			0.8%	10,203	10,376

TECHNICAL APPENDIX 3: CONSUMPTION ANALYSIS RECOMMENDATIONS

This appendix provides recommendations for program year (PY) 2021 residential standard offer, hard-to-reach and low-income programs in response to the PY2019 EM&V residential consumption analysis results. The goal of these recommendations is to most effectively address differences in the technical reference manual (TRM) deemed savings and actual savings for the primary measures investigated in the consumption analysis. These recommendations were discussed with the TRM Working Group and each utility individually as part of the PY2019 EM&V results meeting.

Introduction

A residential consumption analysis of the standard offer, hard-to-reach and low-income programs was conducted as part of the PY2019 EM&V effort. The residential consumption analysis demonstrated that these programs are delivering significant savings to participants, measured by how much less energy they use annually. At the same time, it also demonstrated that the TRM deemed savings are overestimating claimed savings for the following measures: central AC, heat pumps, duct sealing, ceiling insulation, and air infiltration. Central A/C is the measure performing most closely to the deemed savings estimates in delivering savings. Air infiltration has the poorest performance in delivering savings comparable to TRM deemed savings. The reader is referred to the Residential Consumption Analysis Technical Appendix A that details consumption analysis results compared to TRM deemed savings by measure across the three programs as well as the supporting data and analysis methodology.

This section includes both PY2021 TRM updates and PY2021 implementation recommendations. The recommendations are based on various analyses of the consumption results and discussions with the TRM Working Group held on July 7 and July 14. A draft memo provided the basis for continued collaboration between the utilities, EM&V team, and PUCT staff in July and August. The goal of the collaboration was to agree on recommendations and incorporate these recommendations prior to launching the 2021 residential programs. This appendix presents the final version of this memo. While the recommendations include further considerations for future program years, we strove to keep recommendations feasible for 2021 implementation while addressing the critical need for more accurate claimed savings.

Next, we summarize observations based on EM&V analysis of what we believe are the primary causes of differences between actual and deemed savings for measures as follows: HVAC, duct sealing, ceiling insulation and air infiltration. We then list the actions to address these causes both in the PY2021 TRM and program implementation.

HVAC

Baselines

Observation: Claiming electric resistance heat as a baseline is a potential driver of differences between TRM deemed savings and consumption analysis results for heat pumps. Other issues may include TRM calculation methodology, or service provider data entry. This issue and proposed solutions also apply to the all envelope measures.

Objective: Ensure accurate selection of baseline equipment and evaluate other potential causes of the savings difference.

Next, we discuss how this objective will be achieved through TRM updates and utility implementation recommendations.

TRM 2021 Updates:

- Update measure requirements to clearly define and track both existing and baseline heating and cooling types, including defining the difference between central electric resistance furnace and electric resistance space heating
- Electric resistance heat baselines may not be claimed in multifamily properties when changing heating types from chiller to heat pump, except when the utility obtains advance review and approval by the EM&V team of project documentation that the planned heating type was electric resistance.
- Update measure requirements to include a tracking system indicator for projects that change heating types so that they can be easily identified in future consumption analyses

2021 Implementation Recommendations for Utilities:

- Track both existing and baseline heating and cooling types
- Track when heating types change so projects can be easily identified in future consumption analyses
- Conduct 100% utility QA/QC of electric resistance heat baselines for the first six months of the program year. After the first six months of PY2021, utilities may choose to decrease to 50% QA/QC of projects for service providers who have achieved a 100% passing rate for a minimum of 30 projects at different locations. Utilities may determine their preferred process to conduct QA/QC (videos, photos, interval meter data, etc.) of electric resistance heat baselines.

Future Considerations:

Utilities can further decrease QA/QC of electric resistance heating baselines based on service provider performance in future program years

Customer Behavior

Observation: Improper use of programmable thermostats designed to optimize HVAC equipment can decrease savings from new equipment (e.g., manual adjustments of thermostats can make heat pumps less efficient by triggering the electric resistance component)

Objective: Promote proper participant use of HVAC equipment and programmable thermostats as part of the program

TRM 2021 Updates:

- None

2021 Implementation Recommendations for Utilities:

- Consider developing and distributing customer education materials on correct HVAC set points and proper use of programmable thermostats

Future Considerations:

- Future EM&V participant surveys should assess the effectiveness of program education on customer use of HVAC equipment and controls
- Adjust TRM heat pump energy use to include backup and auxiliary electric resistance heat

Duct Sealing

Multi-family versus single-family

Observation: Multi-family consumption results for this measure are substantially less than single-family

Objective: Deliver duct sealing consistent with where actual savings occur based on the consumption analysis.

Next, we discuss how this objective will be achieved through TRM updates and utility implementation recommendations.

TRM 2021 Updates:

- Limit eligibility to single-family homes
- Modify documentation requirements to increase confidence in inside-to-outside testing only
- Apply an energy use multiplier for electric resistance heat that does not use duct systems (e.g., space heating)

2021 Implementation Recommendations for Utilities:

- Conduct 100% utility QA/QC of electric resistance heat for the first six months of the program year. After the first six months of PY2021, utilities may choose to decrease to 50% QA/QC of projects for service providers who have achieved a 100% passing rate for a minimum of 30 projects at different locations. Utilities may determine their preferred process to conduct QA/QC (videos, photos, interval meter data, etc.) of electric resistance heat.

Future Considerations:

- Consider tracking primary and secondary heating and cooling systems
- Utilities can further decrease QA/QC of electric resistance heating based on service provider performance in future program years
- Assess the TRM alternative streamlined approach and results of this approach
- Consider if a multi-family option should be developed and offered in future program years
- Review best practices across other utility programs and identify opportunities for Texas

Ceiling Insulation

Baselines