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ENERGY EFFICIENCY AND DEMAND-RESPONSE: TOOLS TO ADDRESS TEXAS' RELIABILITY CHALLENGES

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ACEEE

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Contents

About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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Key Takeaways

- Texas has major electric reliability challenges, particularly during summer heat waves and major winter cold fronts.
- Texas's growing population and accompanying load growth are driving increased electricity demand. Between 2018 and 2022, the state's population grew by 5% and Electric Reliability Council of Texas (ERCOT) peak load grew by 9%.
- Energy efficiency (EE) and demand response (DR) programs (DR is sometimes called "load shifting") can substantially reduce summer and winter peak demand in the near future, dramatically reducing the chance of blackouts or brownouts.
- We find that a set of 10 energy efficiency and demand response retrofit programs for residential and commercial buildings and equipment, deployed aggressively under statewide direction over the 2024–2030 period, could serve more than 13 million Texas households and offset almost 15,000 MW of summer peak load and 25,300 MW of winter peak load, exceeding the 10,000 MW capability of the 10 new gas plants proposed as "insurance" by some power plant developers.
- ENERGY STAR® heat pumps, smart thermostats, and electric vehicle demand response save the most; they could yield a 17,500 MW winter peak reduction at an average cost of about $101 million per year, or about $41 million per 1,000 MW of winter peak reduction. These programs plus DR programs for central air-conditioning (the largest summer peak reducer) can reduce summer peak by about 8,800 MW at an additional average annual cost of about $128 million per year.
- The set of energy efficiency and demand response programs proposed here would cost about $1.2 billion per year for seven years. That is substantially below the costs of legislation recently enacted by the Texas legislature and lower still when additional costs for generator fuel, maintenance, and transmission infrastructure for those "insurance" generators are included. We also provide a scenario where approximately 80% of the peak demand benefits are achieved for about half the cost of the full package.
- These programs are highly cost effective on their own and compared to generation options. Over the 2024–2030 period, customers will on average receive $20 per month in benefits at an average monthly fee of $7; the benefits more than offset the increased energy efficiency program fee on customer bills. Customers get improved reliability plus energy bill savings.
- These efficiency measures will continue delivering comfort and energy bill savings to program participants, and peak load reductions for all customers for 10 to 20-years. Moreover, they will continue working in extreme weather, unlike some of Texas's power plants.
- Ongoing investment in EE and DR could continue growing these customer savings benefits over time, while giving ERCOT and the Public Utility Commission of Texas time to stabilize the supply-side power market rules and infrastructure.

Executive Summary

Texas Has Substantial Electric Reliability Problems

Texas has recently experienced major electric reliability problems or close calls on multiple occasions due to a combination of extreme weather (hot or cold) and failures of its power system. Despite multiple actions by Texas state and utility officials, more change is needed to address growing power demand in the state and periodic equipment failures. In May 2023, the Electric Reliability Council of Texas (ERCOT, which supplies electricity to 90% of Texans) forecast record peak demand for the summer of 2023 and adequate power availability *unless* there is a confluence of extreme heat, widespread outages at fossil fuel plants, and low renewable energy output; the convergence of these three events is highly possible.

Texas's most dramatic recent reliability event occurred during Winter Storm Uri in February 2021, when ERCOT had to cut electric service to over 4.5 million customer meters for multiple days of extremely cold weather. This event reflected the extraordinarily high demand for electric home heating (from inefficient homes and equipment) combined with the loss of 50% of the state's generation fleet (due to freezing weather, reduced fuel supply, and equipment failures). Supplies were again tight in December 2022 during Winter Storm Elliott, when low temperatures led to some gas outages. ERCOT has also faced recent summer supply challenges, as illustrated by calls for voluntary power conservation in June 2021, summer 2022, and summer 2023. In June 2021, the shortage was driven by a large number of plants being out of service for unplanned repairs. In summer 2022, record demand nearly exceeded available generation supplies, but blackouts were averted by a mixture of operating extra plants to keep reserves high, industrial demand response, and requests for households to raise their thermostats. Together, these measures cost over $3 billion in 2022. In summer of 2023, during a long "heat dome" event, multiple new peak demand records were set, but power cutbacks were averted due to a continuation of the 2022 measures as well as substantial increases in output from Texas' renewable electricity generators. ERCOT's evolving generation resource mix is changing quickly while load is expanding rapidly, so the energy-only wholesale market design is challenged to adapt effectively.

Texas's growing population and accompanying load growth are driving increased electricity demand. Between 2018 and 2022, the state's population grew by 5%, and ERCOT peak load grew by 9%. Texas's population increased by 23% from 2008 through 2022, with little check on electric usage from energy-efficient building codes or utility efficiency programs.

Potential Solutions

Texas policymakers have proposed numerous supply-oriented solutions to address these problems, including winterization of existing power plants and critical grid infrastructure, subsidized construction of many new power plants, and additional financial incentives to reward dispatchable generation. In order to address Texas' reliability challenges, in May 2023 the Texas legislature adopted two bills. One focuses on adding new quick-start gas generation. The bill offers up to $8.2 billion of state funds for 3% loans for new power plants, bonuses for plants completed in the next three years, and maintenance loans to existing generators. The legislation (Senate Bill 2627) puts the loan program on the November 2023 ballot for voter approval. The other bill, House Bill 1500, includes a provision directing the Public Utility Commission of Texas (PUCT) to establish a program to provide additional reliability payments to power generators. Under this program, annual net costs are capped at $1 billion per year. Details will need to be worked out by PUCT, with the program likely beginning in 2027. It is unclear how much these plans will help reliability.

Another way to improve ERCOT reliability is to manage demand as well as supply, expanding Texas utilities' currently limited energy efficiency (EE) and demand response (DR) programs,[1] with a focus on programs that can substantially reduce summer and winter peak demand. A variety of proven and targeted EE and DR measures could be used immediately to address Texas's electric reliability and affordability challenges. Texas has some very good EE and DR programs, but they have low goals with low funding; they could be expanded to complement new power plant additions, slowing energy demand growth at lower cost than just relying on traditional supply-side solutions.

This Report: Energy Efficiency and Demand Response as Tools to Address Texas's Reliability Challenges

EE and DR solutions are the focus of this report, which explores the impact of a set of utility-administered EE and DR programs largely targeting the residential sector, but with a few commercial sector programs.[2] Current Texas EE and DR programs direct the bulk of their efforts toward commercial and industrial customers. But since nearly half of ERCOT's summer and winter peak loads come from residential customers' weather-sensitive loads (ERCOT 2021b), and Texas investor-owned utilities deliver energy efficiency to fewer than

[1] In 2021 (the last year for which data are available), Texas ranked 36th in the country on energy efficiency savings as a percentage of electricity sales and 37th in the country on energy efficiency spending as a percentage of MWh electricity sales, behind such states as Arizona, Arkansas, Indiana, Oklahoma, and Utah (Subramanian et al. 2022).

[2] This paper focuses primarily on EE and DR opportunities in the residential sector because there are large untapped opportunities for EE and DR in this sector. We also include two commercial sector programs in areas not addressed by most current investor-owned utility programs.

30,000 Texas households (Tetra Tech 2022) out of Texas' 10.2 million households[3] per year, residential electricity use is an underutilized efficiency target that can have immediate, strategic impact on peak loads. These programs could be ramped up more quickly than power plant construction and could have significant impact on peak demand beginning in the summer of 2024.

This report is a major update and expansion of a 2021 ACEEE report on this subject. In this new report we update our prior work, account for new federal funds that will soon reach Texas, and add new programs serving low-income households plus two commercial sector opportunities. We also update the perspective to the 2023 situation.

Findings

We find that this set of 10 EE and DR retrofit measures, deployed aggressively under statewide direction over the 2024–2030 period, could serve over 13 million Texas households and offset about 14,800 MW of summer peak load and 25,300 MW of winter peak load (see figure ES-1). The proposed set of EE and DR programs would have a total cost over the 2024–2030 period of about $8.4 billion (average of $1.2 billion per year across the entire state of Texas). These findings are for all of Texas; since ERCOT represents about 90% of Texas loads, impacts for ERCOT can be estimated by multiplying these figures by 90%. We also provide a scenario where approximately 80% of the peak demand benefits are achieved for about half the cost of the full EE and DR package.

For comparison purposes, ERCOT wholesale electric costs exceeded $32.2 billion in 2022 (Bivens 2023), and total retail electric bills were about $39.8 billion in 2021 statewide (EIA 2022). During the 2023 legislative session, the legislature considered a proposal to build 10 GW of new natural gas-fired generation at a capital cost of $18 billion (Buchele 2023), with additional downstream costs for generator fuel, maintenance, and transmission infrastructure.

Once installed, these efficiency measures will continue delivering continuous comfort and energy bill savings for the host customers, and peak load reduction and lower energy bills for all customers in Texas and ERCOT over the course of their 10- to 20-year measure lives. Ongoing investment in EE and DR could continue growing these customer savings benefits over time, while giving ERCOT and the PUCT time to stabilize the supply-side power market rules, infrastructure, and costs.

[3] https://www.census.gov/quickfacts/fact/table/TX/PST045222. In addition to customers served by investor-owned utilities this figure includes customers served by public utilities of which the two largest are Austin Energy and CPS Energy.

This paper looks at 10 specific retrofit EE and DR programs selected for their proven capability to reduce summer or winter peak electricity demand. This paper estimates these programs' potential to improve Texas's and ERCOT's system reliability by cutting summer or winter peak loads or delivering grid flexibility services.

Efficiency measures

- Program to replace electric furnaces with ENERGY STAR® heat pumps
- Attic insulation and sealing incentive program
- Heat pump water heaters incentive program
- Smart thermostat incentive program (an efficiency program that helps enable the DR program listed below)
- Set of energy efficiency programs serving low-income homeowners and renters, including low-cost kits distributed by community groups and more comprehensive whole-home retrofit programs for single-family homes and multifamily apartments
- Small commercial and industrial retrofit program
- Monitoring-based commissioning program for large commercial buildings[4]

Demand response measures

- Central air conditioner/electric heating with smart thermostat control
- Water heater timing controls
- Electric vehicle managed charging

Most of these measures can be used to reduce peak demand in both the summer and the winter. However, small commercial and industrial (C&I) saves a lot more in the summer than in the winter, and electric furnace replacement primarily reduces winter loads and peaks.

If these programs are implemented at wide scale with suitable levels of program investment beginning in 2024, by 2030 they could deliver enough summer peak savings to eliminate nearly 19% of Texas's all-time summer peak as of this writing (82,592 MW in July 2023). Similarly, prompt and aggressive efficiency and demand response investments starting in 2024 could reduce 2030 winter peak load by about 30% of what the peak would have been in February 2021 had power been provided to all customers without power shutoffs (estimated 78,000 MW; ERCOT's documented winter peak was 74,427 MW in 2022). These

[4] Monitoring-based commissioning is a process developed at Texas A&M that uses data from building energy management systems that are common in large buildings, along with some additional strategically placed sensors to help analyze and optimize building operations. Typical energy savings of about 9% can be achieved.

energy efficiency programs will reduce annual electricity consumption by about 14,500 million kWh of electricity by 2030, a relatively small proportion of future electric energy consumption—but these programs are intentionally designed to reduce peak summer and winter demand (MW) and not just reduce energy use (MWh). Savings by year are shown in figure ES-1.

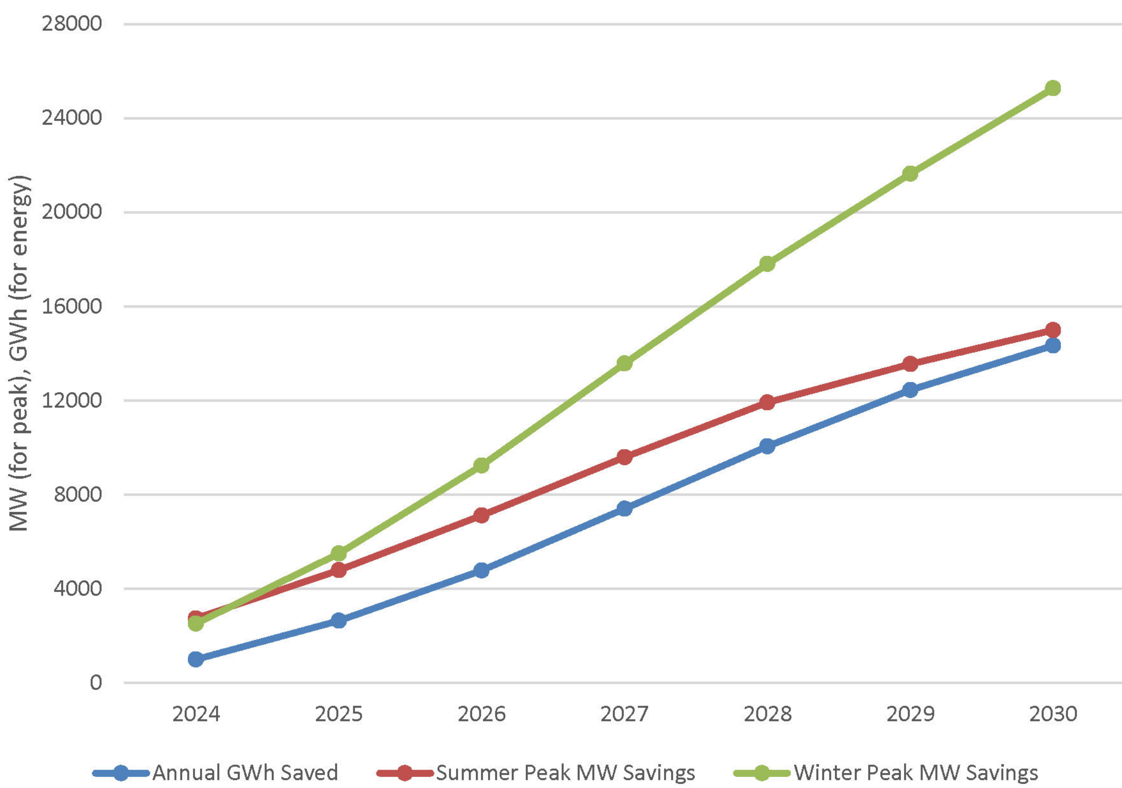


Figure ES-1. Cumulative annual energy and peak savings by year from the sum of the programs analyzed

Results by program are summarized in table ES-1 at the end of this executive summary. The largest winter peak reductions (over 10,000 MW by 2030) come from replacing electric furnaces with heat pumps. The largest summer peak reductions (about 4,000 MW by 2030) are from central air conditioner demand response. The attic insulation and sealing program delivers the largest energy savings (about 5,000 million kWh in 2030) while also delivering 1,900 summer peak MW and 2,400 winter peak MW in 2030. This program is also valuable because better-insulated homes are more effective for sustainable demand response and occupant comfort. This program accounts for about 40% of the total cost of the 10-program package but is foundational to make heating and cooling measures more effective. The smart thermostat and heat pump water heater programs have the best benefit-cost ratio.

The bottom line is that the EE and DR programs examined will deliver large benefits to Texas consumers and utilities. Consumers will benefit from the following:

- Reduced peak demand in summer and winter
- Improved grid operations from fast, controllable demand flexibility tools
- Lower energy bills
- More stable electric production costs
- Improved comfort, safety, and health

Utilities will see reduced capital needs because lower demand will decrease needed transmission and distribution investments. ERCOT and Texas residents will benefit from a more reliable grid that is less vulnerable to increasing extreme weather events.

These measures focus on residential EE retrofit measures, since Texas's large stock of old, inefficient homes is where much of the state's energy waste is occurring. But since Texas's population and economy are growing at robust rates, Texas can and should capture additional long-term energy savings and avoid locking in additional energy waste by adopting more rigorous energy efficiency standards for all new building construction.

Texas is now at a crossroads. The state can continue on the same path that led to massive power curtailments in February 2021 and more limited ones in summer of 2021 and 2022. Or Texas can diversify its energy portfolio by tapping the huge potential of inefficient homes, buildings, and appliances to create EE and DR resources that save money and improve reliability for all Texans.

Table ES-1. Estimated cumulative seven-year costs, savings, and households served for 10 residential energy efficiency and demand response programs targeting peak demand reductions

Program	Customers served	Peak savings in 2030 (MW) Summer	Peak savings in 2030 (MW) Winter	Energy savings (GWh)	Costs ($million)
Efficiency					
Replace electric furnaces with Energy Star HP	602,933	86	10,154	1,281	302
Attic insulation/sealing and duct sealing	2,180,980	1,907	2,435	4,992	3,420
Smart thermostats	2,764,622	1,355	3,029	2,488	276
Heat pump water heaters	299,385	222	383	636	82
Monitoring-based commissioning	735	300	125	1,315	215
Small C&I	86,301	1,077	718	2,734	876
Low-income (sum of 3 subprograms)	2,224,912	869	1,532	2,012	1,816
Subtotal	8,159,868	5,816	18,377	15,459	$6,987
Demand Response					
Central AC/electric heat demand response	2,611,032	3,988	1,476		1063
Water heater demand response	2,224,000	904	1,130		389
EV charging demand response	750,000	4,286	4,286		380
Subtotal	5,585,032	9,178	6,892		1,832
TOTAL	13,744,900	14,994	25,269	15,459	$8,819
Add 13.75% reserve margin		17,056	28,744		

Customers served include some households that participate in more than one program.

Notes: These savings are for all of Texas and include investor-owned utilities, large municipal utilities (Austin Energy and CPS Energy, both of which are already implementing many of these programs), and smaller co-ops and municipal utilities. HP = heat pumps; AC = air conditioning; EV = electric vehicle.

The allowance at the bottom for reserve margin reflects the impact of reduced demand on needed generating capacity. ERCOT targets a 13.75% reserve margin; we use this figure for our calculations.

Introduction

Texas has recently experienced major electric reliability problems or close calls on multiple occasions due to a combination of extreme weather (hot or cold) and failures of its power system. Despite multiple actions by Texas state and utility officials, more change is needed to address growing power demand in the state and periodic equipment failures. In May, the Electric Reliability Council of Texas (ERCOT, which supplies electricity to 90% of Texans) forecast record peak demand for the summer of 2023 and adequate power availability *unless* there is a confluence of extreme heat, widespread outages at fossil fuel plants, and low renewable energy output (ERCOT 2023a). The convergence of these three events is highly possible; in June 2023, Texas and neighboring states experienced an unprecedented heat wave and high levels of thermal plant outages, mitigated by unusually high levels of renewable generation (Rampell 2023). At a May 2023 press conference, then Public Utility Commission Chairman Peter Lake stated "The Texas grid faces a new reality…. Data shows, for the first time, that the peak demand for electricity this summer will exceed the amount we can generate from on-demand dispatchable power. So we will be relying on renewables to keep the lights on," he continued (Walton 2023a).[5] Grid reliability has become a significant political issue and all Texans would like to see a more reliable and affordable power system. Energy efficiency (EE) and demand response (DR) are effective and cost-effective ways to help achieve this goal.

Texas's most dramatic recent reliability event occurred during Winter Storm Uri in February 2021, when ERCOT had to cut electric service to over 4.5 million customer meters for multiple days of extremely cold weather. This event reflected the extraordinarily high demand for electric home heating (from inefficient homes and equipment) combined with the loss of 50% of the state's generation fleet (due to freezing weather, reduced fuel supply, and equipment failures). Supplies were again tight in December 2022 during Winter Storm Elliott, when low temperatures led to some gas outages. ERCOT has also faced recent summer supply challenges, as illustrated by calls for voluntary power conservation in June 2021 and summer 2022. In June 2021, the shortage was driven by a large number of plants being out of service for unplanned repairs. In summer 2022, record demand nearly exceeded available generation supplies, but blackouts were averted by a mixture of operating extra plants to keep reserves high, industrial demand response, and requests for households to raise their thermostats. Together, these measures cost over $3 billion in 2022 (Bivens 2023). In the summer of 2023, in addition to the measures employed the previous summer, ERCOT was able to benefit from a substantial increase in renewable power generation (Joselow 2023) that in turn was driven by federal tax credits combined with state policies that made it fairly easy to develop new projects (Rampell 2023). ERCOT's evolving generation resource

[5] In fact, renewables produced about one-third of the electricity consumed during ERCOT's peak hours during the extended June 2023 heat dome event (Rampell 2023).

mix is changing quickly while load is expanding rapidly, so the energy-only wholesale market design is challenged to adapt effectively.

Texas's growing population and accompanying load growth are driving increased electricity demand. Between 2018 and 2022, the state's population grew by 5%, and ERCOT peak load grew by 9%. Texas's population increased by 24% from 2008 through 2022, with little check on electric usage from energy efficient building codes or utility efficiency programs (EDF, TCA, and ASC 2021).

Power demand in Texas typically peaks on hot summer days, and as a result, ERCOT has emphasized summer peak loads in its planning. The all-time summer peak was 82,592 MW on July 18, 2023 (ERCOT 2023d). Winter Storm Uri in February 2021 produced record cold temperatures (e.g., a low of 4°F at Dallas-Fort Worth airport (DFW Weather 2021)), in turn causing drastic cuts in electricity services for many Texas customers. Sharp, unexpected increases in power demand played an important role in the tragedy, although ultimately too many electric generators failed to perform in the extremely cold weather.[6] In terms of power supplied, this was technically not a winter peak for Texas because load was shed to match the available, limited supply of generation. The all-time Texas winter peak demand is 74,427 MW set in 2022 (ERCOT 2023b). In February 2021 the peak was just over 60,000 MW but would have been about 78,000 MW or higher without load shedding (ERCOT 2021a).

A 2023 journal paper by a mechanical engineering professor and several researchers at the University of Texas examined how the ERCOT load is evolving and what that will mean for the 2025-2050 period. They find that

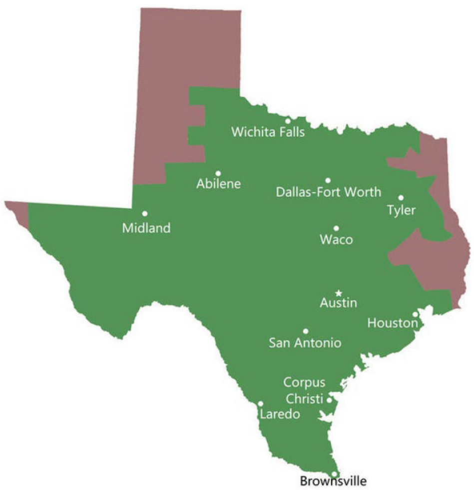
> … historically, summer peak demand growth has been generally stable and approximately linear with time. Conversely, the winter peak demand growth has been less consistent, varying much more around the broader trend. These phenomena are likely consequences of temperatures that were fairly constant on summer peak demand days, but varied widely on winter peak demand days. The erratic nature of winter peak demand is also likely caused by the fact that electrical heating equipment becomes increasingly inefficient at lower temperatures … Additionally, historical winter peak demand was shown to be growing more quickly than summer peak demand. This phenomenon is likely the result of increases in electrical efficiency of cooling and increases in electricity consumption that result from the rising penetration of electrical heating equipment that replace gas furnaces. Future peak demand scenarios indicate that winter peak demand will remain more erratic and will sporadically surpass summer peak demand between 2025 and 2050. Thus, resource planners in ERCOT should place less certainty on winter peak demand projections

[6] For example, see Wood et al. 2021.

> and an increased level of winter preparedness on both the supply and demand sectors appears warranted for resource planners (Skiles, Rhodes, and Webber 2023).

Skiles et al. correctly, in our view, capture the high uncertainty of winter peak demand. In the past 10 years, with one exception, the annual low temperature in Dallas ranged from 11–28°F. The one exception was a low of 2°F in 2021 during Winter Storm Uri (Current Results 2023). But as the climate gets warmer, summer peak demand may also become more volatile.

Power Providers in Texas and ERCOT



ERCOT manages wholesale power supply for about 90% of Texas load, covering 8 million customer meters and 26 million people. Small portions of the state along the borders are covered by other wholesale power pools (see brown shaded zones in map). Within ERCOT, most of the electricity is generated by independent, non-utility generators. Seventy-five percent of customers can select their own competitive retail electric provider (REP). REPs buy electricity from generators, and the power is transmitted to homes by transmission and distribution utilities. These utilities administer Texas's regulated energy efficiency programs. The other 25% of customers in ERCOT are served by cooperative or municipal utilities that do not participate in retail competition. Munis and co-ops are not required to implement Public Utility Commission regulations for energy efficiency and demand response but may implement the programs of their choice.

Source: Shen et al. 2021

In order to address Texas' reliability challenges, in May 2023 the Texas legislature adopted two bills. One focuses on adding new quick-start gas generation. The bill offers up to $8.2 billion of state funds for 3% loans for new power plants, bonuses for plants completed in the next three years, and maintenance loans to existing generators. The legislation (Senate Bill 2627) puts the loan program on the November 2023 ballot for voter approval. The other bill, House Bill 1500, includes a provision directing the Public Utility Commission of Texas (PUCT) to establish a program to provide additional reliability payments to power generators. Under this program, annual net costs are capped at $1 billion per year. Details will need to be worked out by PUCT, with the program likely beginning in 2027. It is unclear how much these plans will help reliability in the near future.

Another way to address these problems is to expand Texas's currently limited set of energy efficiency (EE) and demand response (DR) programs, prioritizing programs that can substantially reduce summer and winter peak demand. Texas utilities offer some good EE and DR programs, but they have limited budgets. Texas's large municipal utilities have more extensive programs and this analysis draws on their experience. Experience in other states demonstrates that using EE and DR can be less expensive and more effective at bringing demand and supply into long-run, lower-risk balance (Lazar and Colburn 2013). And examinations of wholesale markets find that "energy efficiency diversifies the resource mix as a cost-effective distributed resource and reduces reliance on fuel sources that can be subject to fluctuating prices" (Baatz, Barrett, and Stickles 2018).

DR programs modify when electricity is consumed in response to price signals, grid conditions, or specific calls from the grid operator or other program coordinator. Many DR programs are dispatchable, in that they can be designed to issue calls to reduce load at times requested by the system operator or electricity provider. For example, such programs may cycle off air conditioners, heat pumps, electric furnaces, water heaters, or pool pumps for a short period of time across a large group of customers to minimize and stagger the aggregate load from these devices across a longer period—flattening the rate of increasing demand during peak hours and reducing the need to call new generation. In terms of minimizing the potential for imbalances between system-wide supply and demand, the role of DR programs is comparable to that of peaking power plants—but DR programs close this gap by reducing demand instead of by generating more power.

DR can be used not just to reduce demand peaks, but also to shift electricity consumption from high cost or high stress hours to hours with abundant low-cost renewables, like moving EV charging and pool pumping to hours with high levels of wind or solar generation. Demand response is a time-varying resource that is called when needed or initiated by customers in response to prevailing power costs or incentive payments.

EE programs reduce energy use, promoting measures that minimize energy waste while providing the same or equivalent services as less-efficient conventional technologies. While dispatchable DR programs can shift electricity use between time periods, EE programs reduce the amount of electric power needed to perform the same amount of work. EE can be thought of as an always-on resource, although specific efficiency measures can be chosen to target summer and winter peaks such as by promoting high-efficiency air conditioners and heat pumps and better insulating homes.

In our analysis we focus on EE measures that reduce energy use during and around summer and winter peak periods. The programs we analyzed mostly save energy when residents are awake.

With Texas's population and economy growing rapidly, additional generation will be needed in the future. EE and DR can slow the timing of this need and avert possible operational emergencies and load-shedding events in the future.

In the 2023 Texas legislative session, the senate passed a bill to gradually expand EE programs to eventually reduce energy sales by 1% per year (Walton 2023b) and passed another bill to make it easier for power providers in Texas to offer DR programs (Silverstein 2023). Neither of these bills passed the House. But in late 2023 or early 2024, the PUCT is planning to start a docket to consider the role EE programs in Texas (T. Harris, director, Infrastructure Division, PUCT, pers. comm., May 2023). This could be an opportunity to expand EE and DR programs in Texas.

ENERGY EFFICIENCY AND DEMAND RESPONSE IN TEXAS

Despite a promising start in the early 2000s, Texas is now far behind other states in deploying EE and DR to manage demand, support customer bill affordability, and reduce the likelihood of damage from future summer and winter extreme weather events. ACEEE's *2022 State Energy Efficiency Scorecard* found Texas ranked 36th among the 50 states in energy efficiency savings as a percentage of electric consumption, and 37th in energy efficiency spending as a percentage of electric utility revenues (Subramanian et al. 2022).

Texas has some foundational energy efficiency policies in place, but they require modernization and higher goals to deliver on the promise of EE and DR as resources on Texas's grid. Texas established the first Energy Efficiency Resource Standard (EERS) in the country in 1999, which established a requirement for utilities to achieve a specified amount of energy efficiency savings annually. Such programs are required to be "cost effective"—that is, the costs to the utility system of running EE programs (e.g., in terms of administration and incentive costs) must be less than their benefits, such as the avoided cost of supply.[7]

Since this policy was enacted, Texas has been leapfrogged by 26 other states and now has the weakest EERS in the country. As the heading in an old report noted "Texas was an energy efficiency leader … then laggard" (SPEER 2014). As a more recent report found, Texas has some creative and effective programs, with program benefits approximately four times greater than costs but much opportunity remains on the table (Oaks 2022). Limited budgets, limited program marketing, and restrictions on the types of programs that can be offered limit what can be achieved (SPEER 2014).

Texas has the opportunity to ratchet up the ambition of this policy. Figure 1 below shows how Texas's EERS, a target of only 0.2% of MWh sales, compares to all other states with such a policy (most of which set goals of 1% or greater, more than five times Texas's savings requirement). Research from the National Renewable Energy Laboratory (NREL) and the Electric Power Research Institute (EPRI) demonstrate that Texas has the potential to catch up to other states, with savings potential beyond 1% per year (NREL 2017; EPRI 2017).

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[7] This is the definition for the Utility Cost Test, which Texas relies on for cost-effectiveness testing (NESP 2021).

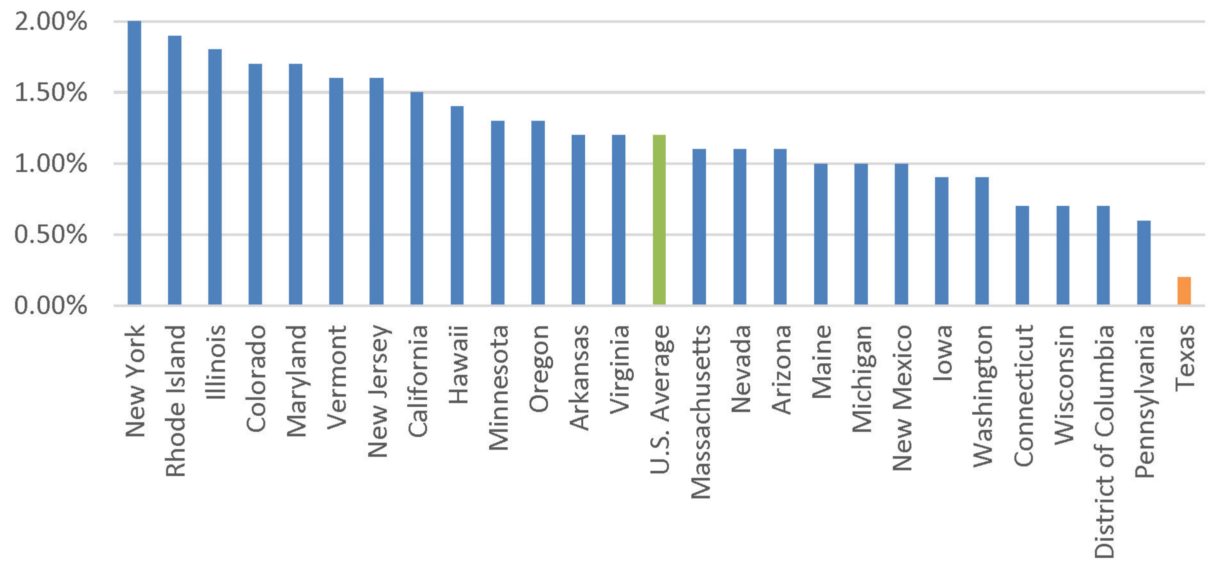

Figure 1. Annual electricity savings as a percentage of state energy MWh sales per state EERS policies. For the purpose of comparison, ACEEE estimated an average annual savings target by calculating each state's EERS savings over the years specified in the EERS policy. State savings are reported on a gross basis; a net adjustment was applied to compare with states' reporting net savings. The U.S. average includes just states with an EERS.

Utilities face particular challenges in serving income-qualified customers, such as prohibitive up-front costs (relative to low-income customers' budgets) for efficiency investments and split incentives for renters. Texas requires that each utility spend a minimum of 10% of its annual energy efficiency budget on targeted low-income energy efficiency programs, and an additional 5% of its budget on hard-to-reach market segments such as multifamily buildings (PUCT 2019). But if overall budgets are small, programs funded with 15% of the budgets have only modest impact.

THIS PAPER

This paper examines how much targeted energy efficiency and demand flexibility could be procured through a range of feasible EE and DR strategies within Texas over the 2024–2030 period. This analysis estimates both potential program costs and potential impacts on peak summer and winter electricity demand, as well as on overall electricity consumption and utility economics (through a simple program benefit-cost ratio from the utility perspective). We focus on the residential sector (single-family and multifamily), as during recent summer and winter peaks, the sector accounts for about 51% of the winter temperature-sensitive load and about 49% of summer temperature-sensitive load (Herbert 2018).[8] Therefore, reductions to Texas household electricity use during summer and winter peaks will translate directly into reductions of those peak loads, as well as reductions in the amount of electric generation, storage, and transmission needed to serve all customers during peak and other grid-stressed periods. In addition to residential programs, we also include two commercial programs.

This report is a major update and expansion of a 2021 ACEEE report on this subject (Nadel, Gerbode, and Amann 2021). In this new report we update our prior work and add new programs serving low-income households and two commercial sector opportunities. We also update the perspective to the 2023 situation.

This analysis is intended to inform PUCT, the ERCOT grid operator, Texas utilities, others involved in utility policy debates, and the Texas legislature as they consider market and regulatory changes to assure power system reliability in Texas. We include a main scenario with an expansion of Texas programs to recommended levels, and also include a scaled-back scenario that is roughly midway between current programs and our recommended set of programs.

The Residential Sector in Texas

According to the U.S. Census Bureau, as of 2019 there were about 10.2 million households in Texas (U.S. Census Bureau 2021a). Of these, about 20% are multifamily, meaning five units or more per building (U.S. Census Bureau 2021b). One-story ranch-style homes with large attic areas are common in Texas. According to federal data, about 30% of homes in the West South Central region (Texas, Oklahoma, Arkansas, and Louisiana) have well-insulated attics and 17% are poorly insulated or uninsulated (EIA 2023). Sealing for air leakage between the attic and living space is often poor. Heating and cooling ducts often are in the attic and many of these are not well sealed, leaking conditioned air into the attic (Miller et al. 2014). The most common type of heating system in Texas is a gas furnace (about 42% of homes) followed by electric heat pumps (about 19%), electric furnaces (a central heating system using inefficient electric resistance heat, also about 19%), and electric resistance baseboard heaters (about 13%). The predominance of inadequately insulated homes and older, low-efficiency electric resistance heating measures (furnaces, wall, baseboard, and plug-in heaters) provides opportunities to reduce energy use and

[8] More recent (2019) values provided by ERCOT are 51% and 48% residential demand load for winter and summer respectively.

peak demand while improving occupant comfort, safety, and survivability over a multi-day power outage.[9]

Methodology

We identified and analyzed 10 potential programs that can have large peak demand impacts—seven EE programs and three DR programs. Eight of these are residential programs, and two are commercial. For each program we estimated the number of Texas homes or businesses that might participate, program costs, and energy and peak demand savings per home (summer and winter). To the extent possible, we used data specific to Texas, such as values from the latest *Technical Reference Manual* (PUCT 2022). Where Texas-specific data were not available, we used data from other states that approximate conditions in Texas as much as possible. In most cases the data were based on electric utility programs in operation.

In our program benefits calculations, we value demand reductions and energy savings at the PUCT official avoided costs of $80/kW-year (one kW of power available over one year) and $0.09113/kWh saved (Harris 2022). A prior PUCT proceeding determined that the electric system saves these costs when EE and DR programs are used to reduce energy use and peak demand. Energy savings estimates include savings on the customer side of the electric meter as well as avoided transmission and distribution losses between the power plant and customer meters, using loss factors calculated by EIA (2022). We modeled each program to run for seven years, starting in 2024, with 2023 used to plan the new programs for launch in 2024. Programs start small and gradually ramp up.

Our analysis looks at all of Texas, within and outside ERCOT, and all types of utilities (investor-owned, municipal, and cooperative.) We recognize that PUCT only regulates investor-owned utilities and that ERCOT does not cover the whole state, making statewide programs unlikely. In the "Recommendations" section, as well as in a few of the program sections, we discuss potential ways to navigate this landscape.

Detailed assumptions, sources, and calculations for each program are provided in the appendix.

[9] For example, after an ice storm in Maine, power outages and subzero temperatures forced hundreds of residents into heated shelters. Yet others in particularly well-sealed homes saw their indoor temperature stay as high as 58 degrees after more than four days, allowing them to safely shelter in place (Cox et al. 2017).

Programs Analyzed

We analyzed 10 potential programs for Texas that could produce substantial reductions in summer and winter peak demand. The programs we analyzed are listed in table 1. We selected these programs based on our understanding of the Texas housing and building stock and ACEEE's 30 years of experience working with electric utilities and states across the nation to design, implement, and evaluate effective EE programs serving every customer sector. The effectiveness and cost effectiveness of the programs below for saving energy and reducing peak demand have been documented in many years of ACEEE's *Utility Efficiency Scorecard* reports (e.g., Relf et al. 2020). Experience has shown that these programs can be cleanly designed and quickly implemented, given appropriate policy direction, programmatic funding, and utility compensation; the cost and impact estimates below are based on other utilities' success and presume that Texas would bring equal commitment to new EE and DR program efforts.

While we classify the analyzed programs as either EE or DR, some technologies enable programs that might straddle these categories. For example, we examine smart thermostats as an EE program because they help customers limit their energy use, but some utilities also use these thermostats as part of their DR efforts. In this case, we analyze and discuss the efficiency benefits and the demand response benefits as separate programs, so as to not double-count their potential benefits. Additionally, attic insulation and sealing (and home weatherization generally) should be viewed as foundational to the effectiveness of most other EE and DR measures, because a home that does not leak conditioned air will enable more economical use of heat pumps, air conditioners, and smart thermostat DR programs. Furthermore, we recommend that these measures be viewed as a portfolio of solutions that should be deployed and evaluated in a coordinated, consolidated fashion, rather than pursuing only a few individual measures from the 10 discussed here.

Table 1. Programs analyzed in this report

Energy efficiency programs	Demand response programs
Replace electric furnaces with ENERGY STAR electric heat pumps	Central air conditioners/electric heat with smart thermostat control
Attic insulation and sealing	Water heaters
Smart thermostats	Electric vehicle charging
Heat pump water heaters	
Package of low-income programs	
Small commercial and industrial	
Metering-based building commissioning	

These programs are primarily for existing buildings, although new construction can participate in most of them. We focus on existing buildings because they will account for the majority of the building stock out to 2050 and beyond (Nadel and Hinge 2023). We also note that for new construction, the best strategy for assuring high efficiency at modest cost is through integrated building designs. This can be done via improved building codes such as continuing to adopt the latest model building codes from the International Code Council and the American Society of Heating, Refrigerating, and Air Conditioning Engineers.

The sections below describe each of these programs and the structure of our analyses. A subsequent section discusses the results for each program, as well as their potential cumulative impacts and costs. For reference, a summary table of results for each program is included with the methodology descriptions below; these results are discussed together in the later sections of this report.

1) REPLACE ELECTRIC FURNACES WITH ENERGY STAR HEAT PUMPS

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Replace electric furnaces with ENERGY STAR HP	602,933	86	10,154	1,281	302

Roughly 20% of Texas households get their heating and cooling from a central air-conditioning system combined with an electric resistance furnace that heats air to be distributed throughout the home via ducts and registers. In 2020, there were more than 1.9 million homes in Texas with such systems (EIA 2023). These homes can be upgraded to use a high-efficiency heat pump at the same time an existing central air-conditioning unit is replaced (a heat pump is essentially an air conditioner that can be run in reverse—providing indoor cooling in the summer, but in the winter operating in reverse to draw heat from outside air and warm the home). Both heating and cooling savings typically result from this upgrade, year-round and at peak times, particularly if the heat pump is a high-efficiency unit as certified under the ENERGY STAR program. Even at winter design temperatures for Texas (the very coldest hours of the year), an ENERGY STAR heat pump will generally be at least twice as efficient (use half as much electricity per unit heat output) as an electric resistance heater. Cooling savings are expected because high-efficiency heat pumps are also more efficient than the average new air conditioner.[10]

For this measure, we assess a program in which Texas utilities give an incentive averaging approximately $500 per home to Texas air-conditioning contractors to encourage them to sell a heat pump instead of an air conditioner when an existing air conditioner needs replacement. This incentive, combined with federally funded grants for heat pumps for households with incomes below 150% of the area median income and federal tax incentives for 30% of heat pump costs up to $2,000 should cover the incremental cost to the contractor of installing a heat pump rather than an air conditioner.[11] Because these incentives will more than cover the incremental cost in most cases, we expect high rates of participation, gradually ramping up to 80% of heat pump purchases in lieu of central air conditioner purchases by year four of the program. While some heat pumps are presently incentivized by utility standard offer programs, available budgets limit the number of projects and programs are only available to some customers. A widely available market transformation program working “upstream” with contractors and wholesalers can increase participation substantially.[12] Contractor training will be an important part of this effort as we discuss in a section on workforce toward the end of this report.

Texas has recently begun using upstream programs for lighting, retail appliances, smart thermostats, and “other efficient equipment” (Tetra Tech 2022), but we could not find specific mention of upstream programs for heat pumps. However, residential upstream programs have been assigned high priority for evaluation starting in 2023 by PUCT, including consumption analyses for high-impact measures such as heat pumps (Tetra Tech 2022). As discussed in the “Results” section, our proposed electric furnace replacement program would have substantial summer peak reductions and the largest winter peak reductions of all the programs we examined.

Significant energy savings might also be obtained from replacement of electric baseboard heaters (which are inefficient and energy wasteful) with heat pumps, but this upgrade is more complicated and costly than replacing electric furnaces. We discuss this possibility in the “Other Opportunities” section of this paper.

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[10] The 2023 ENERGY STAR specification for air conditioners and heat pumps requires either two-speed or variable speed operation, which can reduce fan energy use by 60% or more compared to conventional air conditioners and heat pumps (EPA 2021; DOE 2016).

[11] Information on both of these programs is discussed by Ungar and Nadel (2022).

[12] For example, a study on upstream incentives by the Southwest Energy Efficiency Project reports that rebates for commercial high-efficiency air conditioners were 5 to 10 times more effective during periods of upstream incentives relative to periods of consumer incentives (Quaid and Geller 2014).

Texas utilities could relieve some local reliability challenges caused by transmission congestion by concentrating the electric furnace, air conditioner, and heat pump replacement strategy in combination with attic insulation and sealing in particular areas facing high demand growth behind transmission bottlenecks. Geo-targeted deployment of EE and DR has been used in other states for high-impact *non-wires solutions*.

Heat Pump Performance in Cold Weather

Our recommendation is that in order to get good cold temperature performance, heat pumps should be ENERGY STAR certified. Our estimated peak demand savings are based on performance at 17°F, a typical annual low in Dallas (Current Results 2023). At this temperature, a typical heat pump will have a coefficient of performance (COP) of about 2.3, more than double an electric resistance system, which has a COP of 1.0. Due to this difference in COP, the heat pump will use 57% less power than an electric resistance system.[13] However, during Uri, Dallas got even colder. At a temperature of 5°F our typical ENERGY STAR heat pump has a COP of 1.69 (Goodman 2019). In addition, at low temperatures, heat output drops and more heat needs to be supplied by backup electric resistance coils, reducing the total COP to about 1.32.[14] But even this represents 24% power savings relative to electric resistance.[15]

2) ATTIC INSULATION AND SEALING

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Attic insulation/sealing and duct sealing	2,180,980	1,907	2,435	4,992	3,420

An estimated 50% of single-family homes in Texas have inadequate attic insulation (NREL 2021), which allows cooled or heated indoor air to return to outdoor temperatures faster

[13] (2.3 – 1)/2.3 = 57% less power.

[14] ACEEE calculations based on data in Goodman 2019.

[15] (1.32 – 1)/1.32 = 24% less power.

than would otherwise occur. This contributes to occupant discomfort and excessive energy bills, while leaving residents vulnerable to extreme temperatures in summer and winter. [16]

Attic upgrades incorporating improved insulation, air sealing, and duct sealing yield heating and cooling energy savings and reduce winter and summer peak demand. Insulating to R-38 or higher is recommended for attics in Texas climate zones (Less and Walker 2015). Increasing insulation to a thermal resistance of R-38 and air-sealing attics in homes currently insulated to R-19 or less would save 10–30% of the annual heating and cooling electricity use for an average Texas home, depending on existing insulation levels and type of heating (e.g., electric furnace or heat pump). Leaky air ducts also contribute to the loss of heated and cooled air; duct sealing could save an additional 4–16% of heating and cooling energy use.

Attic insulation, air sealing, and duct sealing directly reduce both summer and winter electricity use and make demand response efforts more effective. A well-insulated home keeps the occupant comfortable under a wider range of outdoor and in-home temperatures improving health and safety during extreme weather and power outages.

For this proposed EE retrofit program, we suggest utility incentives covering 50% of customer project costs in years one and two of the program to ramp up participation. For year three and four, the utility incentive falls to 40% of project costs, before dropping to 30% for the final three years of the program. We estimate that over seven years, 30% of Texas homes could be served under this program. In areas where contractors are available, typical attic insulation and associated air sealing costs about $2,250, and duct sealing costs $1,250, for a total project cost of $3,500 on average. Attic insulation and duct sealing are common measures in utility standard offer programs, but the reach of these programs has been severely limited by available budgets.

Federal incentives enacted under the 2022 Inflation Reduction Act (IRA) will increase the incentives available for insulation and air sealing projects. The High Efficiency Electric Home Rebate Program (HEERH) provides up to $1,600 to low- and moderate-income households for insulation and air sealing. The Home Energy Rebate Program provides incentives for larger projects achieving at least 20% home energy savings; incentives start at $2,000 and are doubled for low- and moderate-income families. Funding for these programs totals $8.8 billion; the Texas share will be about $690 million (DOE 2022a). In addition, the IRA provides tax credits of up to $600 for insulation materials.

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[16] Excessive energy bills place a particularly high burden on low-income residents in cities and rural areas. ACEEE research characterizes energy burdens at the national and regional level as well as 25 metro areas including Houston, Dallas, and San Antonio (Drehobl, Ross, and Ayala 2020). Weatherization including attic insulation and duct sealing is a leading strategy for significantly reducing high household energy burdens.

Of the programs we included in our analysis, the attic insulation and duct sealing program yields the third largest summer peak impacts and the largest electricity savings.

The program design proposed above for attic insulation, air sealing, and duct sealing in single-family homes may not be effective for low-income and multifamily housing, where the residents may have neither the money nor capability to initiate and co-fund an EE upgrade. At least 40% of Texas households are low and moderate income (TEPRI 2021) and just over 20% live in multifamily housing (U.S. Census Bureau 2021b), offering ample opportunity for peak and energy savings. Considering the peak reduction opportunity along with social and economic equity, we recommend that the Texas PUC expand their current low-income programs to deliver EE cost effectively to more residents in these communities. Proposed offerings are outlined under section five (“Low Income Programs”).

3) SMART THERMOSTATS

Program	Customers served	Peak savings in 2030 (MW)*		Energy savings (GWh)	Costs ($millions)
		Summer	Winter		
Smart thermostats	2,764,622	1,355	3,029	2,488	276

***Per the 2023 Technical Reference Manual (TRM), demand savings cannot be claimed for connected thermostats. Demand savings can only be claimed for customers enrolled in an AC load management program. Connected thermostats offer significant summer and winter peak demand savings regardless of participation in peak demand management programs, which are limited to the highest summer peak demand events.**

Smart thermostats provide energy savings and demand reduction by simplifying residents’ control and management of air-conditioning and heating systems, and by adjusting to variations in home occupancy patterns. Like programmable thermostats, smart thermostats save energy by raising cooling temperature setpoints and lowering heating setpoints when the home is unoccupied or while occupants are sleeping. Smart thermostats have the potential to save more energy than programmable thermostats by automating setpoint changes, responding to actual home occupancy, and allowing for remote operation and control. The widespread use of central air-conditioning and heating in Texas households makes smart thermostat use an option for many residents. A number of municipal utilities and cooperatives in Texas offer rebates for smart thermostats; other utility customers may be eligible for discounts or incentives as well (e.g., CenterPoint and Oncor customers can get coupons for $50 to $65 toward the purchase of a smart thermostat).

We propose an incentive program offering $50 (or thermostat cost, whichever is lower) for installation of ENERGY STAR-certified smart thermostats. Prices for ENERGY STAR thermostats range from $58 to $380; all of the major manufacturers offer products for less than $125 (Enervee 2023). Higher incentives will likely be needed for low- and moderate-income households. Smart thermostats are popular products and can generally be installed by competent homeowners. We estimate participation will ramp up to reach 30% of eligible participants cumulatively over the seven-year program. Program implementors can increase savings and customer satisfaction by coupling incentives with consumer education campaigns focused on effective use of smart thermostats for energy savings and improved comfort.

Annual energy savings per unit are based on a review of smart thermostat programs and savings included in state technical resource manuals (Snell and Valentine 2020). This yields a more conservative savings estimate than the estimate we derived using the deemed savings tables in the Texas Technical Resource Manual (PUCT 2022 with weighting to account for climate zone and heating equipment type). Even with this more conservative estimate, the savings are substantial. Programs can increase savings by facilitating participant enrollment in a central AC demand response program (discussed below). Presently, some smart thermostats are installed via utility standard offer programs, but the number of homes that can receive thermostats appears to be limited by available budgets.

4) HEAT PUMP WATER HEATERS

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Heat pump water heaters	299,385	222	383	636	82

Water heating represents the second largest source of residential energy demand after heating and cooling (EIA 2023). As of 2020, 54% of Texas households use electricity for water heating (EIA 2023). Heat pump water heaters (HPWHs) are much more energy efficient than electric resistance water heaters (ERWHs); this represents an opportunity to reduce demand across more than five million households. Texas electricity providers including Austin Energy and SWEPCO currently offer rebates on heat pump water heaters, varying in size of incentive (Austin Energy 2023; SWEPCO 2023).

We propose an incentive program providing a $300 rebate to Texans to replace an electric resistance water heater with an ENERGY STAR-certified electric HPWH, generally at the end of life (13-year average life) for the current water heater. Austin Energy provides this level of incentive to customers installing an ENERGY STAR-certified HPWH. This amount covers about half the incremental cost of replacing an ERWH with a HPWH instead of another ERWH, per values reported in a recent U.S. Department of Energy (DOE) analysis (DOE 2022b). Low- and moderate-income households will be eligible for federal HEERH rebates of up to $1,750 for HPWHs. Consumers may also claim a tax credit for 30% of the cost of a high-efficiency HPWH up to a maximum of $2,000. As noted in the PUCT 2021 Statewide

Energy Efficiency Report, adoption of HPWHs has been slow; contractor education and expanded consumer education and marketing are needed in addition to rebates (Tetra Tech 2022).

We assume 8% of the state's water heater fleet will come due for replacement caused by failure annually (in line with a 13-year lifespan estimate based on DOE standards) and estimate participation will ramp up 2% each year from 4% of replacements in the first year to 16% in 2030. Annual energy savings and seasonal demand savings are estimated based on deemed values for replacement of an ERWH with a HPWH in the Texas Technical Resource Manual (PUCT 2022), weighted across climate zones and indoor conditions (details in the appendix).

The next three programs were not included in our 2021 report. Two of these—low-income and small commercial programs—aim to provide services to key customer groups who often get left behind and will not be fully served by either current Texas utility programs or by the new programs discussed above. These are relatively expensive programs because these two customer segments have limited resources and cannot generally provide much up-front capital to help pay for energy efficiency measures. The third program—monitoring-based building commissioning—uses an approach first developed at Texas A&M University to obtain substantial energy and demand savings from large commercial buildings.

5) LOW-INCOME PROGRAMS

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Low-income efficiency kits	1,791,552	67	334	623	47
Low-income single-family	303,367	707	1,056	1,106	1,636
Low-income multifamily	130,023	95	143	283	134
Total (sum of 3 subprograms)	2,224,912	869	1,532	2,012	1,816

Low-income households in Texas often struggle to pay energy bills (TEPRI 2019) and appear to be less likely to participate in current EE and DR programs than higher-income households. This is likely the case for many reasons such as limited knowledge about program offerings, limited time to participate (many low-income households work more than one job), lack of money to pay customer cost shares, and limited program marketing in low-income areas. Increasingly around the country, utilities are offering targeted programs for low-income households working with local community groups that are trusted in low-income neighborhoods and with high incentives so that most of the costs are covered by the program (Morales and Nadel 2022). In Texas, more than 30% of households meet the most widely used definition of low-income, which is a household income less than 200% of the federal poverty level.

In Texas, both Austin Energy and CPS Energy in San Antonio have operated targeted low-income programs for many years. We model a statewide program that is based on the Austin and CPS programs. Texas investor-owned utilities also offer a variety of programs targeting low-income customers, but these programs have limited budgets—in 2021, total spending on these programs was $25.6 million (ACEEE analysis of utility spending data compiled by Tetra Tech), which is about 10% of the average annual budget for our recommended programs. Our recommended low-income program has three components:

1. Kits
2. Single-family retrofit
3. Multifamily retrofit

Kits are sets of low-cost measures that can be distributed to households and mostly installed by a household member. Kits will typically include a few light-emitting diode (LED) lightbulbs, water-saving showerheads and faucet aerators, door or window draft guards, and other low-cost measures. Evaluations of kit programs indicate that many households install at least some of the measures; estimated savings are based on these evaluations. Kit programs can serve many households quickly. We recommend that trusted local community groups be enlisted and funded to help distribute kits at no cost to recipients and provide installation advice.

More comprehensive retrofits typically include insulation, finding and sealing air leaks between conditioned space and unconditioned spaces, insulating pipes and ducts, and sealing leaks in ducts. We separately model a single-family and multifamily program, the former largely based on the CPS program and the latter based on programs run by Austin Energy and Commonwealth Edison. We assume that the number of homes and apartments served gradually ramps up, with about 30% of eligible homes and apartments served by 2030.

For the kits, we estimate an average cost of about $50 per household including the kit and other program costs. For comprehensive weatherization, costs average a little over $5,000 per single-family home and a little over $1,000 per apartment. Avoided cost benefits of the kit and multifamily programs are at least triple the costs and should be high priorities. For the single-family program, costs and avoided-cost benefits are about the same, but this does not include additional benefits such as improved resident comfort and health.

6) MONITORING-BASED COMMISSIONING

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Monitoring-based commissioning	735	300	125	1,315	215

Large new commercial buildings are typically commissioned when they are first occupied to adjust heating, ventilation and air-conditioning (HVAC) and other systems and try to ensure they are working properly. However, systems tend to get out of adjustment over time and need to periodically be recommissioned. The evolving state of the art is often called monitoring-based commissioning and involves looking at data on building operations and setpoints on a continuous basis and identifying and solving problems as they occur. The technique was pioneered at Texas A&M University in the Department of Mechanical Engineering under the name Continuous Commissioning.

The Texas A&M Continuous Commissioning approach involves a visit by a team of engineers to understand the building, adjust systems, and set up monitoring (typically using the building management system) to continue to monitor the building remotely and inform building managers about problems that need to be addressed. Texas A&M has done this process on more than 500 buildings and has achieved average electricity savings of about 11% (Ruffin, Claridge, and Baltazar 2021). Other notable programs are operated by Commonwealth Edison (Com Ed), the utility that serves Northern Illinois and the New York State Energy Research & Development Authority (NYSERDA). The Com Ed program now has three components: Monitoring-Based Commissioning for the largest buildings, Retro-Commissioning Flex primarily for medium-sized buildings, and Virtual Commissioning that includes smaller buildings, particularly chains and other groups of buildings under common management (Nadel 2023). The NYSERDA program was designed to make Real Time Energy Management common practice for large commercial buildings in New York State. NYSERDA has certified more than a dozen vendors and more than 1,000 buildings, achieving average energy savings of 8.2% (NYSERDA 2023). Some Texas utilities presently offer retro-commissioning programs as a one-time service. Our recommended program takes this to the next level to help achieve continuous, ongoing savings.

For our analysis we assume a program that targets buildings with a floor area of 50,000 sq. ft. or more as these are the buildings that typically have a building management system. The program would use Texas A&M and a variety of contractors and would build on the lessons learned from the Texas A&M, Com Ed, and NYSERDA work. Assumptions are based on these three programs. The program would pay 25 cents per square foot of floor area served, which is approximately one-third of the cost of monitoring-based commissioning; building owners would pay the rest. We assume that 3% of targeted buildings participate each year, resulting in providing service to 21% of targeted in buildings in year seven (2030).

While the current building commissioning programs described above target energy savings (kWh), the NYSERDA program has done a lot to help manage building peaks, since buildings in New York generally pay a demand charge based on their maximum building demand over the prior 12 months. Unfortunately, NYSERDA only collects data on kWh (and also fuel) savings and does not estimate the peak savings of their program. Our peak savings estimates are thus based on the other two programs, neither of which emphasizes peak savings. We believe greater peak savings are possible, but given the lack of data on these savings, we take a conservative approach and only include the kW savings that are incidental to the kWh savings.

If buildings with Continuous Commissioning were also targeted for remote demand response and demand control measures, participating property owners and the Texas grid could realize greater savings. Based on limited data from an Automated Demand Response program operated by Pacific Gas & Electric Company, we think that with automated demand response, peak demand savings for this program can be about twice what we estimate here (Nadel 2023).

7) SMALL BUSINESS DIRECT INSTALLATION

Program	Customers served	Peak savings in 2030 (MW)		Energy savings (GWh)	Costs ($million)
		Summer	Winter		
Small C&I	86,301	1,077	718	2,734	876

Small commercial customers tend to be hard to serve with EE measures because they have a limited number of staff and often there is no decision maker except for the busy business owner. When programs offer rebates for businesses, generally a lower percentage of small customers request rebates than is the case for larger customers. Many utilities have found that the best way to reach small businesses is to provide a “direct installation” package of measures where utility contractors identify measures to install from an approved list and the utility provides a grant to cover much of the cost, and sometimes easy-to-access financing for the rest (York et al. 2015). In Texas, Austin Energy and CPS Energy offer programs of this type and some investor-owned utilities offer more limited programs. We based the statewide small business program we analyzed on results from the Austin and CPS programs, assuming an average cost per business served of about $10,000, with the program serving about 25% of eligible businesses by 2030.

Traditionally, small business direct installation programs emphasize lighting retrofits. LED lighting is becoming more common, but small business adoption of LED lighting tends to lag adoption by larger businesses (Kula 2023), so there still may be small business lighting opportunities for a few years. But after a few years the measures installed under this program will have to change, with more focus on controls for HVAC, lighting, refrigeration, and plug-loads.

8) CENTRAL AIR CONDITIONER/ELECTRIC HEATING DEMAND RESPONSE

Program	Customers served	Peak savings in 2030 (MW)		Costs ($million)
		Summer	Winter	
Central AC/electric heat demand response	2,611,032	3,988	1,476	1,063

Austin Energy, CPS Energy (serving San Antonio), and El Paso Electric have DR programs to either cycle residential air conditioners during a limited number of peak demand periods or to use a smart thermostat to raise the setpoint during this period. Historically these programs have cycled air conditioners using radio paging technology, but most new installations are using smart thermostats with Internet connectivity.[17] Consumers receive a discount on the thermostat and/or a monthly payment or credit during summer months. AEP Texas and CenterPoint used to offer such a program; Oncor's program is currently closed.

We propose a program that would offer demand response services to all Texas residents with central air conditioners, modeled on the Austin and San Antonio municipal programs.[18] We propose both cost-sharing on the thermostat and regular payments during the summer months to help keep participants motivated to remain in the program. Austin does not provide such payments and has seen a significant number of consumers leaving the program (Austin Energy 2021). The cost-sharing of the thermostats may include some double-counting of costs with the smart thermostat program discussed above. The peak

[17] Programs are moving to smart thermostats because they regulate temperature directly, helping to maintain occupant comfort—and also because smart thermostats provide energy savings outside of the peak, as described in the smart thermostat program above. With radio control, air conditioners are cycled off and at times temperatures can move outside of occupant comfort ranges.

[18] While we recommend that all utilities implement such a program, we recognize that this may be hard to execute in practice. For example, municipal utilities and electric co-ops are not regulated by PUCT. One option might be that ERCOT implement such a program, covering the 90% of the state that it serves, with some additional participants added from PUCT-regulated utilities outside of ERCOT.

savings from this program are in addition to the peak savings from the smart thermostat program. San Antonio has experimented with various ways to control thermostats and achieved the largest savings with a specific schedule they developed to maximize impacts (CPS Energy 2019). Our peak demand impacts are based on the savings from a 33% cycling schedule, which are about the same as the CPS schedule (details in the appendix). As discussed in the "Results" section, this program has the largest summer peak impact of all the programs we examined.

Since thermostats control both heating and cooling, smart thermostat DR can also be used in winter emergencies (as San Antonio and Austin did during Winter Storm Uri). This application significantly increases the value of smart thermostat investments. We propose that the program offer an additional incentive payment to customers for participating in a winter demand response program. This program would be offered to those customers participating in the summer central air conditioner demand response program who have a heat pump or an electric furnace. Florida Power and Light currently offers a similar program and more utilities around the country are beginning to add winter demand response programs to their portfolios. Adding winter DR to the program provides very cost-effective flexibility to address winter reliability issues and makes the overall program more attractive to customers.

Extensive experience in numerous states indicates that DR programs have higher customer retention over an operating season and over multiple years if the utility or other implementer that is managing the curtailments conducts excellent communication with customers about when and why DR events are happening. The most effective DR programs also offer meaningful compensation to participating customers for their inconvenience and exercise some moderation in the number, magnitude, and duration of temperature shifts. Such efforts are important to ensure that these programs retain high numbers of participants, so that they can collectively deliver a predictable and substantial demand response while exposing participating households to tolerable temperature swings.

Out of all the programs reviewed in this paper, smart thermostats are the only measure that is routinely offered by Retail Energy Providers (REPs) and curtailment providers (e.g., OhmConnect, Octopus Energy, Google Nest, and MP2) today. This means that utility investments in smart thermostats could help grow the pool of residential DR participants faster, to provide greater dispatchable load relief and operational flexibility to the ERCOT grid.

Smart thermostats and remote curtailments or cycling of heating and air-conditioning load have received negative press in Texas and elsewhere. We recommend that PUCT encourage investment in customer education campaigns about how these programs respect and protect customers' preferences and the value of these programs for saving money and protecting grid reliability for all.

9) WATER HEATER DEMAND RESPONSE

Program	Customers served	Peak savings in 2030 (MW) Summer	Winter	Costs ($million)
Water heater demand response	2,224,000	904	1,130	389

Water heater demand response programs enable a utility to shift or curtail energy use of water heaters through a control device retrofitted or built into the heater. Curtailment of demand from these devices may provide an attractive option during severe peak events driven by high or low temperature extremes, as impacts to consumers from temporary reductions in hot-water temperature are far less significant than the loss of heating, cooling, or other essential power uses.

We propose a program that would offer demand response services to all Texas residents with electric water heaters with hot-water storage tanks, including ERWH and HPWH. The program would install and pay for the water heater control device when required—new water heaters are increasingly sold with the controller already integrated. We assume after-market control devices will be available for a lower bulk or wholesale rate than the retail cost of devices sold directly to individual consumers. We further propose that annual payments be provided to motivate continued participation. Potential reductions of load per participating water heater are estimated based on an average of several reported or estimated values identified in literature (see details in the appendix). We also reduce anticipated demand savings for the estimated HPWH fleet to 50% of those from ERWHs (see details in the appendix.)

10) ELECTRIC VEHICLE MANAGED CHARGING

Program	Customers served	Peak savings in 2030 (MW) Summer	Winter	Costs ($million)
EV charging demand response	750,000	4,286	4,286	380

Electric vehicles (EVs) currently constitute a small fraction of vehicles titled in Texas, but their numbers are growing rapidly.[19] ERCOT and the Texas Department of Motor Vehicles estimate Texas could have one million electric vehicles by 2028 and 2031, respectively (TX DOT 2022). This growth represents a major potential challenge to grid operators in terms of new electric load to absorb; the collective EV infrastructure also presents an opportunity to smooth daily load curves through proactive managed charging. However, the retail structure of Texas's electricity market complicates the implementation of some forms of managed charging.

DR measures involving electric vehicles include both time-of-use and direct load control (often called managed charging) models. Time-of-use (TOU) programs vary retail electricity rates to encourage charging during off-peak hours, while managed charging models enable a managing entity to directly control the participant's EV charger and reduce its power draw when needed. San Antonio's CPS Energy offers both TOU and managed charging programs as of 2021 (CPS Energy 2021).[20]

Although TOU programs have been highly effective at incenting EV off-peak charging, under current rules PUCT cannot impose such programs upon competitive REPs. However, transmission and distribution utilities (TDUs) and demand aggregators could use managed EV charging programs to deliver dispatchable demand reduction, as could owners of public charging stations. Pursuing this infrastructure would also help lay the foundation for future vehicle-to-grid power measures (Davar 2020), which could offer significant peak reduction and demand flexibility services in a future with high rates of EV adoption.

[19] According to the Texas Electric Vehicle Registration Tool (https://bit.ly/3C1CbQV), there were 196,729 EVs registered in Texas as of May 23, 2023. This is a one-month increase of 6,524 from the 190,205 registered as of April 25, 2023.

[20] The Smart Electric Power Alliance study *Managed Charging Programs: Maximizing Customer Satisfaction and Grid Benefits* provides a useful summary of customer research and findings from program experience to date as well as case studies showcasing a number of program approaches.

We propose a managed charging program to reward customers for charging their vehicles in times other than peak and net peak hours, particularly to soak up excess wind or solar generation. We estimate high participation in such a program based on survey responses conducted by the Smart Electric Power Alliance (SEPA 2019a), which suggest that 72% of EV owners would be willing to charge their vehicles at off-peak hours and actual experience from California utilities showing that 70–90% of residential EV charging occurs during off-peak hours under lower time-of-use rates (CA IOUs 2022). We model an up-front payment to enroll in this program, supplemented with declining annual payments to continue participation.

Special Considerations for Rural Households

Given Texas' vast size, programs face challenges delivering services to rural customers. The number of contractors available to serve rural communities and the time and fuel costs associated with reaching remote customers create barriers to participation. There are options to support efficiency upgrades for rural residents. Programs can target rural communities and arrange to work with multiple households at the same time, making it more profitable for contractors. Innovative practices like the use of remote audits to pre-screen homes and identify necessary upgrades in advance can eliminate the need to visit the home prior to measure installation. Homes with limited access to internet or spotty cellular coverage can participate in demand response programs including AC and water heater demand response utilizing radio-signal controls on their equipment, a common practice among rural cooperatives across the country. The bottom line is that careful thought needs to be given to serving rural residents and modifications made to programs operated in denser sections of the state. McPherson, Gilleo, and Ferguson (2018) discuss some examples and some of the issues involved.

Other Opportunities

In addition to the proposed solutions discussed above, there are additional opportunities for peak demand reduction from residential programs. These include

- *Swimming pool pumps*. Texas has at least half a million swimming pools (Katz 2016). Pool pumps can be controlled through either a demand response program or automated standard time-shift to morning operation, reducing peak summer demand by more than 1 kW per pool (Energy Solutions 2020).
- *Batteries*. A growing number of Texas homes are installing battery storage, either in conjunction with solar photovoltaic systems or as a backup for when the power goes

out. Some utilities are paying customers to use these batteries to run their homes during peak or net peak demand periods, reducing the load on the utility (SEPA 2019b). Alternatively, with proper wholesale market incentives and permissions, ancillary service aggregators could use distributed batteries to mitigate the rate of evening solar photovoltaic ramp-down on system net peak demand and frequency.

- *Room air conditioners*. Some Texas homes and rental multifamily housing use room air conditioners that could be managed for demand response, as Consolidated Edison has done in New York City and as Eversource is now doing in Connecticut (Tweed 2012; Eversource 2021). It could also be beneficial to conduct widespread replacement of old, inefficient window air conditioners with high-efficiency window air conditioners in areas with dense, older multifamily housing.
- *Baseboard heaters.* While many Texas homes use electric furnaces, some have electric baseboard heaters. These can be replaced with "mini-split" heat pumps, although costs will be higher than the electric furnace replacement program outlined above (Nadel and Kallakuri 2016).[21] Another option for some homes will be new high-efficiency window heat pumps (Galluci 2022).

There are also large opportunities in the commercial and industrial (C&I) sectors to reduce peak demand. Texas utilities and ERCOT already have some demand response programs that can be expanded. Texas utilities have some existing C&I energy efficiency programs, but these have emphasized lighting upgrades. Now that LED lighting is becoming one of the most common types of lighting in commercial buildings, Texas utilities should transition C&I programs to focus more on heating, ventilation, and HVAC, weather-sensitive loads that are higher during peak periods. [22] Our proposed monitoring-based building commissioning program begins to get at that opportunity, but much more is possible. For example, there are efficiency opportunities through employing intelligent control strategies (Rogers et al. 2013) as well as opportunities to manage and shift loads through grid-interactive efficient buildings (GEB) strategies (DOE 2021).

Results

We find that this set of 10 EE and DR retrofit measures, deployed aggressively under statewide direction over the 2024–2030 period, could serve over 13 million Texas households and offset almost 15,000 MW of summer peak load and 25,300 MW of winter peak load (see figure 2), nearing 20% of ERCOT's record peak load levels. The proposed set

[21] Mini-split air conditioners and heat pumps are typically mounted high on a wall and can cool and heat a room or set of rooms. They are common in Asia and Europe and becoming increasingly common in the United States. Further information is provided in a *New York Times* article (Mahony and Sawyers 2021).

[22] The new Commercial Building Energy Consumption Survey found that 44% of U.S. commercial buildings used LED lighting in 2018 (EIA 2021b).

of energy efficiency and demand response programs would have a total cost over the 2024–2030 period of about $8.8 billion, substantially less than the capital, fuel, maintenance, and transmission costs of new natural gas plants with comparable power output. These findings are for all of Texas; since ERCOT represents about 90% of Texas loads, impacts for ERCOT can be estimated by multiplying these figures by 90%.

Once installed, these efficiency measures will continue delivering continuous comfort, energy bill savings, and peak load reduction for all customers in Texas and ERCOT over the course of the measures' 10- to 20-year lives. Ongoing investment in energy efficiency and demand response could continue growing these customer savings benefits over time, while giving ERCOT and PUCT time to stabilize the supply-side power market rules and infrastructure.

This report looks at 10 specific retrofit and demand response measures selected for their proven capability to reduce summer or winter peak electricity demand. This report estimates these measures' potential to improve Texas's and ERCOT's system reliability by cutting summer or winter peak loads or delivering grid flexibility services.

Efficiency measures

- Program to replace electric furnaces with ENERGY STAR heat pumps
- Attic insulation and sealing incentive program
- Heat pump water heaters incentive program
- Smart thermostat incentive program (an efficiency program that helps enable the demand response program listed below)
- Set of energy efficiency programs serving low-income homeowners and renters, including low-cost kits distributed by community groups and more comprehensive whole-home retrofit programs for single-family homes and multifamily apartments
- Small commercial and industrial retrofit program
- Monitoring-based commissioning program for large commercial buildings

Demand response measures

- Central air conditioner/electric heat with smart thermostat control
- Water heater
- Electric vehicle managed charging

Most of these measures can be used to reduce peak demand in both the summer and the winter. However, air conditioner demand response is a summer-only program, small C&I

saves a lot more in the summer than in the winter, and electric furnace replacement primarily reduces winter loads and peaks.[23]

PEAK DEMAND SAVINGS

If these programs were implemented at wide scale with suitable levels of program investment beginning in 2024, by 2030 they could deliver enough summer peak savings to eliminate about 19% of Texas's all-time summer peak (82,592 MW; ERCOT 2023d). Similarly, prompt and aggressive EE and DR investments starting in 2024 could reduce 2030 winter peak load by about 30% of what the peak would have been in February 2021 had power been provided to all customers without power shutoffs (estimated 78,000 MW; ERCOT 2021a; ERCOT's documented winter peak was 74,427 MW in 2022; ERCOT 2023b). The energy efficiency programs will reduce annual electricity consumption by about 14,500 million kWh of electricity, equivalent to the annual power draw of about 1,150,000 Texas homes. Savings by year are shown in figure 2.

[23] Most of the savings are during the heating season. However, on average heat pumps are a little more efficient in the summer than cooling-only air conditioners. This is the case because year-round operation increases energy savings, making higher levels of heat pump efficiency cost effective.

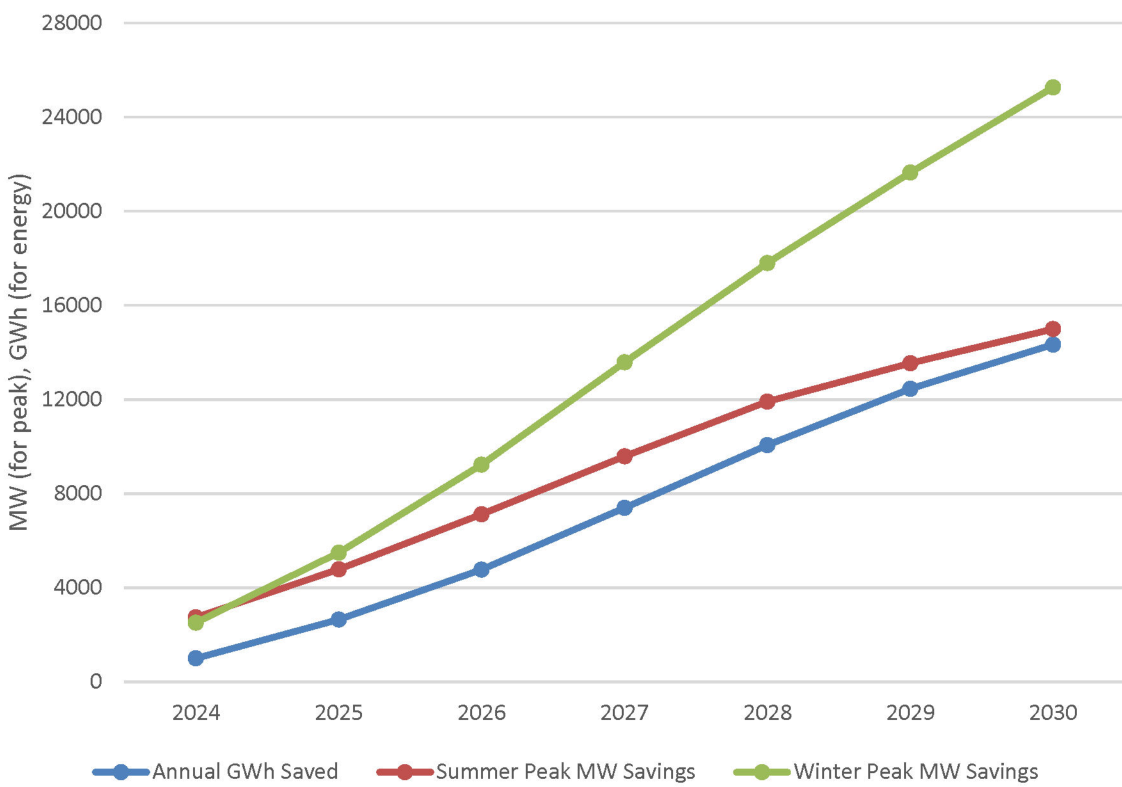
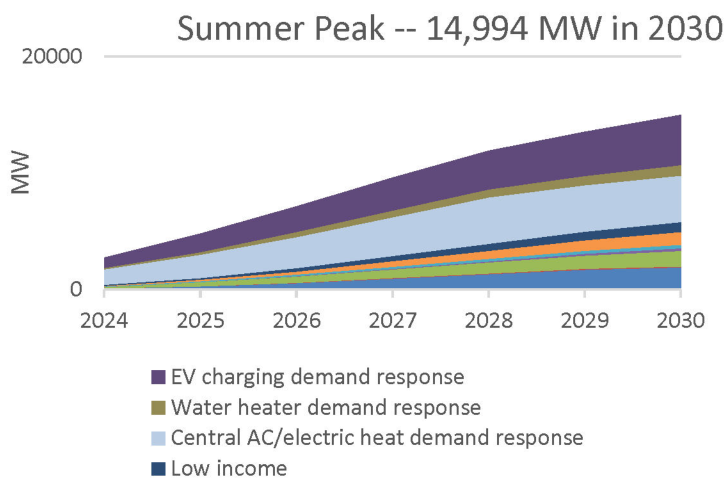


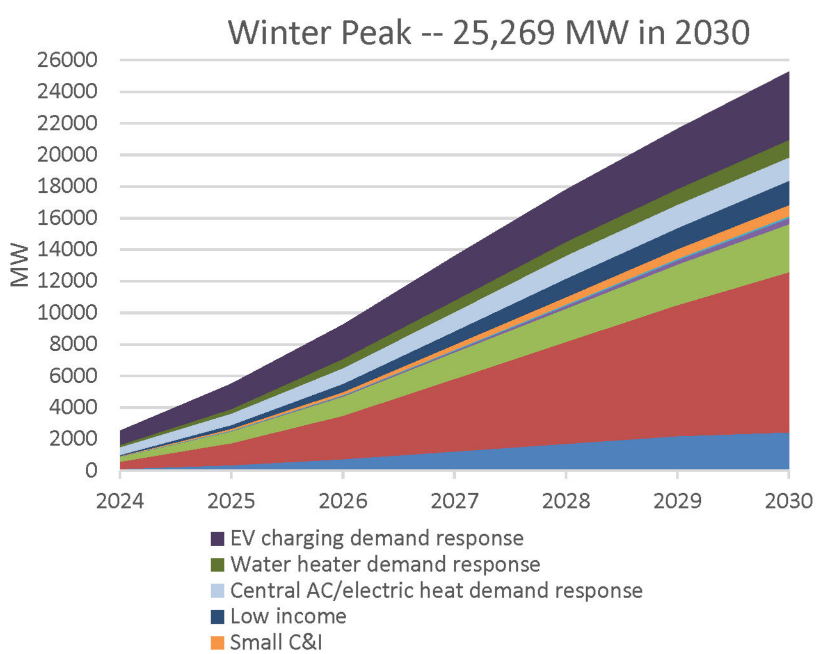
Figure 2. Cumulative annual energy and peak savings by year from the sum of the programs analyzed

Results by program are summarized in table ES-1. The largest winter peak reductions (over 10,000 MW by 2030) come from replacing electric furnaces with heat pumps. The largest summer peak reductions (about 4,000 MW by 2030) are from central air conditioner demand response. Peak demand reductions by program are illustrated in figure 2. The attic insulation and sealing effort delivers the largest energy savings (about 5,000 million kWh in 2030) while also delivering 1,900 summer peak MW and 2,400 winter peak MW in 2030. This program is also valuable because better-insulated homes are more effective for sustainable demand response and occupant comfort. This program accounts for about 40% of the total cost of the 10-program package but is foundational to make heating and cooling measures more effective. The smart thermostat and heat pump water heater programs have the best benefit-cost ratios.

Figures 3 and 4 show how much each energy efficiency and demand response program would contribute to summer and winter peak load reduction. If these programs are implemented with sufficient funding and smart program delivery plans between 2024 through 2030, these programs could cut Texas's summer peak loads by almost 15,000 MW and winter peak loads by 25,300 MW. If implemented aggressively, these programs will deliver meaningful reliability benefits well before 2030—note that this suite of programs could reduce peak summer load by over 4,000 MW in 2025, which would offset the equivalent of the 4,000 MW of thermal generation in ERCOT that were out of service on unplanned outages during the June 2023 heat wave.

In an important distinction from current Texas demand response programs, these programs would require the electric utilities to recruit additional new participants every year, not merely maintain current customers. Alternatively, PUCT could expand the overall energy efficiency program structure to enable REPs to also access the efficiency program funds to recruit, grow, and retain the number of efficiency and demand response participants over time.





Figures 3 and 4. Summer peak (top) and winter peak (bottom) demand savings by year and program

The demand reductions delivered by these programs prevent not only the need for power generation equal to the amount of avoided energy use by consumers but also the need to generate additional energy typically lost during the electricity delivery process. Our estimated savings include a 5.34% average estimated distribution loss factor (EIA 2022), representing power that would have been generated and lost through transmission and distribution.

Reducing power demand also reduces the size of ERCOT's needed reserve capacity. If we add a 13.75% reserve margin to the estimated power savings achievable through our analyzed programs (ERCOT's targeted minimum; ERCOT 2023c)—representing reserve capacity no longer needed because of the system-wide demand reductions—the avoided generating capacity in 2030 totals about 16,900 MW in the summer and 26,800 MW in the winter (shown in table ES-1). This increase in estimated demand savings stemming from the reduced need for reserve margin is over 2,000 MW in the summer and over 3,000 MW in the winter, equivalent to the generation capacity of at least 2–3 additional gas-fired combined-cycle power plants (note that we do not include this reserve margin in our estimates that follow of cost effectiveness of the total suite of analyzed programs, nor in our reporting of the energy and demand savings potentials of individual programs).

These energy and peak reductions also reduce ERCOT costs by reducing the amount that Texas electric customers have to pay for energy scarcity mark-ups (the ERCOT Operating Resource Demand Curve (ORDC)), aggressive ERCOT operational reliability non-spinning reserve and reliability unit commitment costs, and transmission congestion and redispatch costs that exceeded $3 billion in 2022 (Bivens 2023).[24]

ENERGY SAVINGS

Energy (kWh) savings by program and year are illustrated in figure 5. The largest energy savings are from attic insulation and duct sealing (5,000 million kWh), small business (2,700 million kWh), smart thermostats (2,500 million kWh), and low-income programs (2,000 million kWh). The DR programs primarily shift energy use from one period to another and deliver very little energy savings.

[24] Includes operating resource demand curve (ORDC) and firm fuel supply service (FFSS).

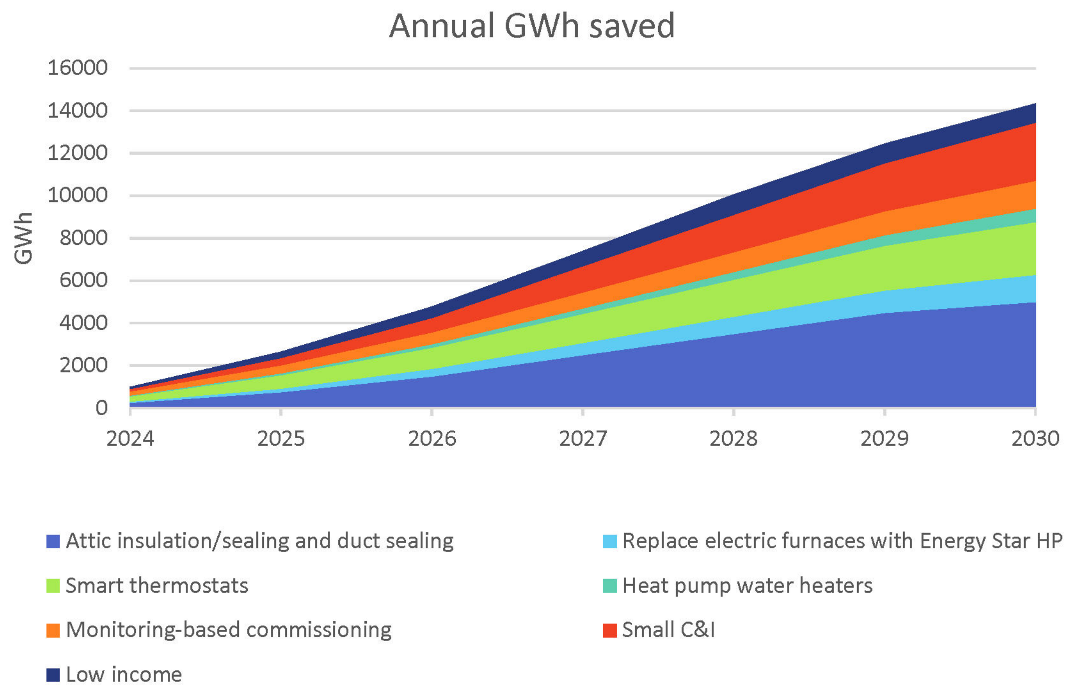


Figure 5. Energy savings (GWh) by program and year

PROGRAM COSTS

The proposed programs will cost about $661 million in the first year (2024), ramping up to about $1.7 billion of spending per year in year four. If these programs were marketed and delivered aggressively over the first four years, spending on the attic insulation program in particular could begin to decline in 2028 as the program starts to saturate its potential market. We recommend that additional efficiency programs be undertaken in 2026 and beyond, to provide additional savings beyond the 10 programs we analyze.

Spending by program and year is shown in figure 6. We recommend that the balance of 2023 be used for program planning, with the programs launching in 2024 and expanding in 2025. New federal energy efficiency grant programs could make substantial contributions to these budgets, particularly to the heat pump, heat pump water heater, and attic insulation programs. The role of these federal programs in helping to reduce costs in Texas are discussed in the program descriptions earlier in this report.

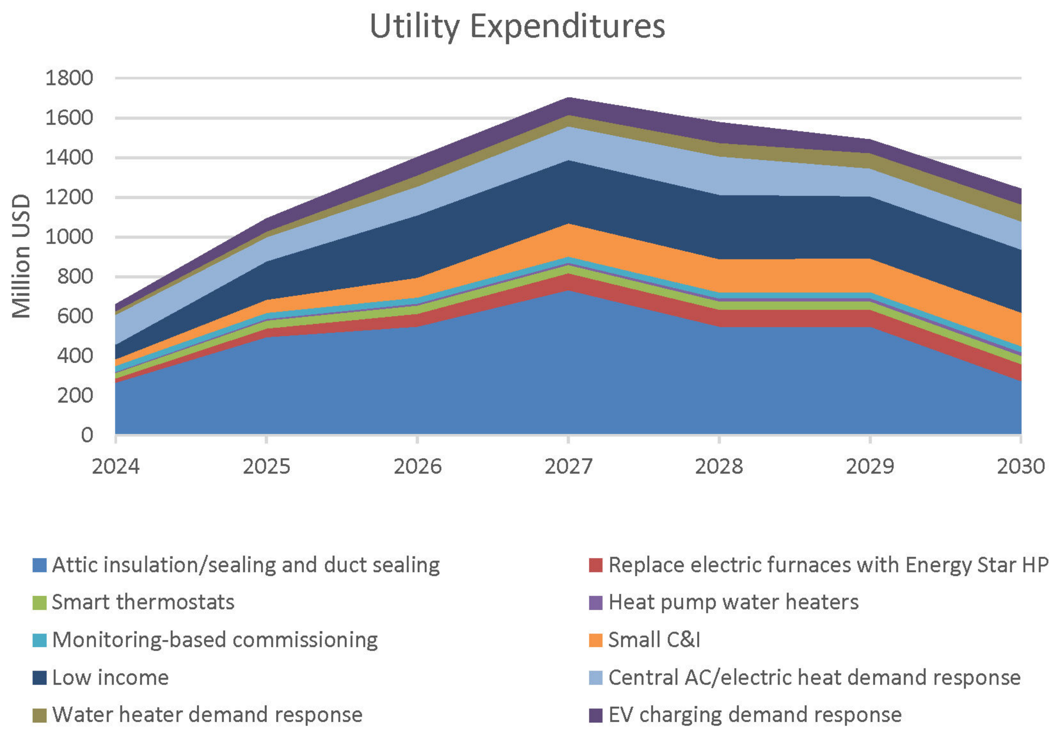


Figure 6. Utility spending by year and program (2023$)

Averaged over the 14.165 million electricity customers in Texas (EIA 2023), the costs of our proposed programs average less than $85 per customer per year, which is about $7 per customer per month. The benefits by 2030 average about $20 per customer per month. Thus, within a few years, aggressive investments in energy efficiency and demand response would raise one fee on customers' bills but lower overall energy bills by three times that fee while improving power system reliability for everyone.

To put these costs and savings in current perspective, in 2021, Texas investor-owned utilities (which excludes the large municipal utilities serving Austin and San Antonio) used energy efficiency and demand response programs to reduce summer peak demand by 571 MW and electricity sales by 775 million kWh (Tetra Tech 2022). The programs proposed here are designed to complement and expand the current Texas programs. Current Texas utility efficiency programs emphasize commercial and industrial savings; these recommended programs focus more on residential customers, including a significant expansion of current low-income program efforts.

While the costs of our proposed programs are substantial in comparison to current efficiency expenditures, they pale in comparison to recent cost increases hitting ERCOT customers' electric bills. Annual ERCOT transmission congestion costs approach $3 billion per year (Doying, Goggin, and Sherman 2023) and ERCOT is spending more than $3 billion per year in scarcity payments to assure that enough power plants are standing in reserve to cover sudden thermal plant outages, a drop in renewable generation, or a surprise jump in demand over forecast levels (Lewin 2023). The expanded efficiency and demand response programs will cost a fraction of the cost of new power plants, which will deliver capacity and energy relief more slowly due to construction time and incur additional annual costs for fuel and maintenance.

The attic insulation and sealing program accounts for about $3.4 billion, which is 41% of the total program costs of all 10 included programs. Insulation costs are high because we estimate an average cost per utility of nearly $1,700 per home for almost 2.2 million participants out of Texas's over 7 million single-family residences. The next most expensive programs are the low-income programs and the central air conditioner DR program, costing about $1.8 billion and $900 million, respectively, over seven years. The former includes three components ranging from under $100 to about $5,000 per home and serves over 2 million families over the seven years. The latter ramps up to over 2.5 million homes but costs much less per participant. As noted earlier, attic insulation and sealing make the DR programs more effective in terms of delivered savings and occupant comfort.

COST EFFECTIVENESS AND GETTING THE MOST BANG PER DOLLAR

The EE and DR program budgets modeled include annual utility operating costs. Over the life of these measures, the average cost of these energy savings is about 4.8 cents/kWh, just over half the 9.1 cents/kWh avoided cost estimated by PUCT (Harris 2022) and less than half the 13.55 cents/kWh average residential electric rate in Texas in 2022 (EIA 2023). And when extreme arctic storms or summer heat waves strike, these measures will already be installed in homes, protecting Texans' comfort and safety with no deliverability or operability challenges.

The paragraph above reflects only avoided energy costs. When we also include avoided demand costs, the programs we propose cost less than half as much as their "avoided cost" as estimated by PUCT (Harris 2022) and therefore will save Texas ratepayers at least two dollars or more for every dollar spent on energy efficiency and demand response.

These numbers do not count the additional benefits that EE offers for recipients' health and safety, reductions in energy poverty and insecurity due to lower electric bills, and lower vulnerability to fuel cost volatility and fuel delivery failures.

We calculated a benefit-cost ratio for each program and overall. As a group, the benefits of these programs are nearly 2.9 times greater than the costs. The ratio is a little higher (better) for the EE programs (over 2.9) than for the DR programs (2.2) since the efficiency programs avoid both peak demand and energy costs and deliver savings year after year. Benefit-cost ratios for individual programs are illustrated in figure 7 and range from 9.4 (heat pump water heaters), to not quite one (for water heater demand response). In addition to heat pump water heaters, Texas should prioritize highly cost-effective programs (benefit-cost ratio greater than four): smart thermostats, heat pumps to replace electric furnaces, EV demand response, and monitoring-based commissioning of large commercial buildings.

Texas should also prioritize the attic insulation program because insulation delivered under that effort makes the heating, air-conditioning, and smart thermostats installed in the same home more effective for customer comfort and savings.

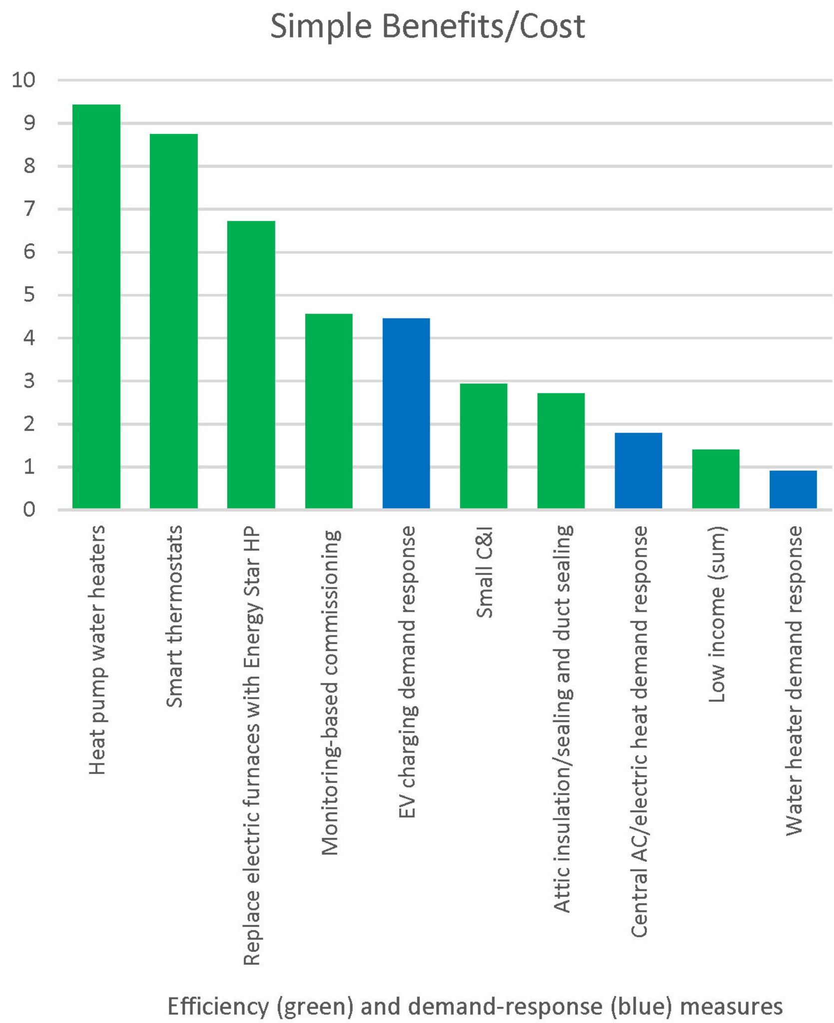


Figure 7. Benefit-cost ratios for individual programs and for all EE and all DR programs

OTHER BENEFITS

Because our benefit-cost analysis is conducted from a utility perspective, our accounting omits the significant potential value of this suite of interventions to participating electricity end consumers. Decision makers should bear in mind the potential value of these measures in terms of improvements to the health, safety, and well-being of millions of Texans.

The potential non-energy benefits (NEBs) of several of these programs include improvements to participant health stemming from direct modifications to the home environment. While precise quantification of the individual health impacts of specific energy efficiency measures remains a challenge, evaluations of NEBs based on weatherization interventions by the federal Weatherization Assistance Program (WAP) suggest that each home weatherized yields several thousand dollars of non-energy benefits, spread between households and society (Tonn et al. 2014).

Basic weatherization measures, including attic insulation and duct sealing, in combination with measures to ensure adequate ventilation and moisture exclusion, correlate with improved resident comfort and fewer extreme indoor temperatures (Wilson et al. 2016). A review of the impacts of more comprehensive weatherization approaches strongly suggests that these measures can reduce in-home stresses and triggers linked to increased frequency or severity of respiratory illnesses like asthma (Wilson et al. 2016). We anticipate that a statewide program of attic insulation and duct sealing would make treated homes safer and more resilient during future extreme weather events in addition to improving comfort and health year-round.

Large-scale programs like those analyzed also offer a highly cost-effective opportunity to identify and address basic health and safety hazards as part of program implementation. For example, a range of such services may be included with in-home efficiency programs funded by WAP (EERE 2017). At grantee discretion, these measures may not only remedy unsafe conditions to allow implementation of energy efficiency measures, but also include simple but impactful benefits like installing smoke alarms and carbon monoxide monitors.

Household energy expenditures are expected to decrease with the energy efficiency program measures, as well as with rebates or incentives connected to all programs. A home's "energy burden" is the proportion of household income spent on energy costs; households with high energy burdens (which are disproportionately low-income and minority households (Drehobl, Ross, and Ayala 2020)) may face impossible decisions between essential expenditures such as adequate heating, sufficient food, and prescribed medication. These so-called "heat-or-eat dilemmas" can create a cascade of negative impacts to a household's health and well-being (Hernández 2016). Benefits to households from reduced total energy expenditures may also translate back into savings for utilities in the form of reduced transmission and distribution costs, reduced collections actions, and reduced disconnection and reconnection activities (Tonn et al. 2014).

Expanding EE and DR programs will also grow the Texas economy. Installation of these measures creates many jobs.[25] And as consumer bills decline due to reduced energy use, consumers generally spend those savings on other goods and services such as home improvements and meals and entertainment. While we did not have time in this study to model the impacts of these programs on the Texas economy, a prior ACEEE study on a

[25] The Texas Advanced Energy Business Alliance estimates that in 2019 Texas had over 254,000 jobs in the energy efficiency sector, even without the significant program expansions recommended here (TAEBA 2020).

somewhat different set of programs estimated that employment gains would be about 5,500 jobs in the first year of expanded programs, growing to 38,000 jobs in the last year of the analysis (Laitner, Elliott, and Eldridge 2007). And as consumers' bills decline due to their reduced energy use, they will generally spend those savings on other goods and services such as home improvements, meals, and entertainment.

PRIVATE SECTOR ROLES

We recommend that distribution utilities be in charge of these programs since they serve all the customers in a specific geographic area and can use economies of scale and geographic targeting to help reduce costs. Retail energy providers could be allowed to offer these services to their customers, preferably offering comprehensive services that serve all customers under the same program rules and cost allotments as the utilities. Short of this, retail providers could offer a much more limited program focused only on smart thermostats. Even where distribution utilities oversee the programs, most of the costs will be for private-market program support contractors and installation contractors such as insulation and air-conditioning contractors.

WORKFORCE FOR ENERGY EFFICIENCY AND DEMAND RESPONSE

These expanded EE and DR programs will require thousands of workers, ranging from insulation installers to skilled engineers. These programs provide an opportunity to create many high-skilled, Texas-based jobs, as installation of measures cannot be imported. We gradually ramp-up participation in our analysis in order to permit a growing workforce to be hired and trained. Training for providing these efficiency services can be leveraged using state and local job training programs.

Under the State-Based Home Energy-Efficiency Contractor Training Grant (CTG) funded in the IRA, Texas is allocated $11.7 million to support contractor workforce development.[26] These programs will be led by the Texas State Energy Conservation Office and can be supported by other relevant state agencies. States meeting the initial application deadline of September 30, 2023, can begin using the funds for 2024 activities. The CTG funds can be used to reduce training costs, provide contractor testing and certification, and support partnerships to develop and implement workforce programs. Of particular note, funds can support training and upskilling of new and existing heating and air-conditioning technicians. We recommend increased efforts to train these technicians via expanded high school and

[26] Program details and application guidelines are available at https://www.energy.gov/sites/default/files/2023-07/IRA-50123-ALRD-Contractor-Training-Program.pdf.

community college technical training programs as well as via combined classroom and apprenticeship programs.

Alternative Scenario with Smaller Program Expansion

We recognize that in the past, Texas policymakers have only supported EE and DR budgets, along the lines of the $130.5 million dollars that Texas investor-owned utilities spent in 2021 (ACEEE analysis of data compiled by Tetra Tech). While we hope that policymakers will seriously consider the full set of programs, we also identified a more limited set of programs that in our view would be the highest priority if only more limited funding were available. In this group of programs, we include the five programs with a benefit-cost ratio greater than 4.0 (replace electric furnaces, heat pump water heaters, smart thermostats, monitoring-based commissioning, and EV demand response) and also included central air-conditioning/ electric heating demand response (nearly 4,000 MW of summer and 1,500 MW of winter peak demand reduction) and half of the attic insulation and low-income programs. These latter two programs both are cost-effective and important complements to the other programs but have large overall costs. To reduce these costs, we scaled them to reduce the number of participants in half.

Overall, this subset of programs will by 2030 reduce summer and winter peak generating requirements by about 13,200 MW and 24,400 MW, respectively (including avoided reserve margins), which are 78% and 85% of the summer and winter peak avoided generating requirements of the full package of recommended programs. Energy savings are 60% of the full package, while costs are $705 million per year on average (less in early years, more in later years), which is 56% of the costs of the full package. Individual impacts by program and overall are summarized in table 2. Comparable figures for the full package can be found in table ES-1.

Table 2. Estimated seven-year costs, savings, and households served for eight programs included in alternative scenario

Program	Customers served	Peak savings in 2030 (MW) Summer	Winter	Energy savings (GWh)	Costs ($million)
Efficiency					
Replace electric furnaces with Energy Star HP	602,933	86	10,154	1,281	302
Heat pump water heaters	299,385	222	383	636	82
Attic insulation/sealing and duct sealing (half)	1,090,490	953	1,218	2,496	1,710
Smart thermostats	2,764,622	1,355	3,029	2,488	276
Monitoring-based commissioning	735	300	125	1,315	215
Low-income (half)	1,112,456	435	766	1,006	908
Subtotal	5,870,621	3,351	15,676	9,222	3,493
Demand Response					
Central AC/electric heat demand response	2,611,032	3,988	1,476		1,063
EV charging demand response	750,000	4,286	4,286		380
Subtotal	3,361,032	8,274	5,762		1,443
TOTAL	9,231,653	11,625	21,437	9,222	$4,936
Scaled-back as % of full		78%	85%	60%	56%
Add 13.75% reserve margin		13,223	24,385		
Annual average (without reserve margin)		1,661	3,062	1,317	$705

Recommendations and Next Steps

We recommend that Texas utilities begin planning for the following 10 programs, all of which have large peak demand savings and appear to be cost effective to the utility:

- Program to replace electric furnaces with ENERGY STAR heat pumps
- Attic insulation and sealing incentive program
- Smart thermostat incentive program
- Heat pump water heaters incentive program
- Central air conditioner demand response program with smart thermostat control
- Water heater demand response program
- Electric vehicle managed charging program
- Low-income program package
- Monitoring-based commissioning
- Small business direct installation

If this is not possible, we recommend the scaled-back programs in the alternative scenario which drops small business and water heater demand response and scales back attic insulation and low-income programs.

We recognize that the path forward to implement these programs must address several barriers and will require creative solutions. Some of these programs can be implemented via the current standard offer approach, but others can benefit from additional approaches. Specific barriers and potential solutions are summarized in table 3.

Table 3. Barriers to expanded EE and DR programs and potential solutions

Barrier	Possible solution
Program participation rates are limited by available budgets.	Increase program budgets by increasing Energy Efficiency Cost Recovery Factors through a change to PUCT rules. Give smaller, often rural utilities an option to offer efficiency measures at higher cost and fee levels and allow them to purchase some savings credits from larger utilities.
Demand response programs emphasize commercial and industrial customers, and residential DR programs are limited except for Austin Energy and CPS Energy.	Have REPs operate residential DR programs or direct the distribution utilities to operate such programs.

Barrier	Possible solution
Current heat pump and heat pump water heater programs are limited and often involve consumer incentives.	Implement a midstream or upstream program by which distribution utilities provide incentives to contractors or wholesalers. [27]

We recommend that 2024 be used for program planning and launch, with programs and budgets ramping up over the 2025–2027 period to maximize near-term demand reductions. Budgets can modestly decline over 2028–2030 as some markets become saturated. New federal programs will complement these budgets, leveraging and expanding the total budget and impact on Texas reliability. PUCT should continue the practice of allowing the utilities that manage these EE and DR programs to earn a share of energy savings, as a way to ensure that the utilities remain committed to excel in delivering these strategically critical programs.

Because one-third of Texans live in poverty or face energy insecurity, we also recommend that the Commission increase the 15% of program budgets currently allocated for low-income households and hard-to-reach customers. For example, Delaware, Montana, New Hampshire, New York, and the District of Columbia all set aside 15–20% of their energy efficiency budgets for low-income households (Berg and Drehobl 2018). We recommend that Texas at a minimum allocate 20% of the available budget to these programs to make up for how little has been accomplished over the energy efficiency program history and begin realizing the significant energy-saving potential of low-income housing.

Taken together, these programs will cost significantly less over this seven-year period than the $8.2 billion that the Texas legislature recently approved to fund low-cost loans for gas-fired power plants and their ongoing fuel, maintenance, and transmission costs. The costs of the energy efficiency and demand response programs that would be charged to all Texas electricity customers are incorporated into our cost estimate through 2030.

The programs evaluated above focus primarily on residential EE retrofits. But Texas is one of the fastest-growing states in the nation, with an extraordinarily high rate of new building construction. We strongly recommend that the state legislature and cities adopt the most recent model energy efficiency building codes to upgrade the quality of new housing and

[27] Texas has recently begun using upstream programs for lighting and retail appliances (Tetra Tech 2020), but we could not find mention of upstream programs for heat pumps.

building stock (including commercial and industrial buildings).[28] This would deliver long-lasting benefits in terms of energy bill savings and grid reliability without any incremental cost to taxpayers or utility customers and would lessen the need for future efficiency retrofits.

Our analysis is a preliminary one, intended to offer ballpark estimates for what energy efficiency and demand response could accomplish quickly in Texas. Additional analysis will be needed to refine these estimates. ACEEE is prepared to conduct a more detailed analysis, looking more fully at program costs, load shape impacts, and rate impacts. We can also conduct an input-output analysis looking at the job impacts of our proposed programs. Utilities should also look at these program details. We look forward to engaging with them through this process.

The bottom line is that the energy efficiency and load management programs we have examined have large benefits to Texas consumers and utilities. Consumers will benefit from the following:

- **Reduced peak demand in summer and winter** will enhance grid reliability by lowering the amount of generation needed to meet customer demands under extreme weather conditions and reduce the generation system's vulnerability to power plant and transmission failures due to extreme weather events, equipment failures and fuel supply interruptions.
- **Improved grid operations from fast, controllable demand flexibility tools can be used to** better balance power demand and supply, particularly with higher levels of renewable resources on the Texas grid. DR measures complementing more stable demand patterns will make Texas much less likely to reach the demand-supply imbalance that triggers power curtailments.
- **Lower energy bills** (due to reduced consumption and reduced need for utility capital expenditures) will be useful for all Texas households but particularly useful for low- and moderate-income Texas households who often face high energy bills as a percentage of their income.
- **More stable electric production costs** and protection against fuel cost variability since the volatile costs of natural gas and coal have increased significantly over the past few years.

[28] Although the Texas legislature approved Senate Bill 2453 in 2023, a measure that would have updated statewide building codes to the latest energy efficiency codes, the Texas governor vetoed that measure in June 2023 as part of a broader political battle (*Houston Chronicle* 2023).

- **Improved comfort, safety, and health** because insulation and sealing will make homes more comfortable and better able to retain temperatures during power outages, among other non-energy benefits.

Utilities will see reduced capital needs because lower demand will reduce or modify needed transmission and distribution investments. ERCOT and Texas residents will benefit from lower electric bills and a more reliable grid that is less vulnerable to increasing extreme weather events.

Texas is now at a crossroads. The state can continue on the same path that led to the massive power curtailments in February 2021 and more limited ones the past two summers. Or Texas can diversify its portfolio by tapping its huge resource of inefficient homes, buildings, and appliances to create energy efficiency and demand response resources that save money and improve reliability for all Texans.

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Appendix. Program Assumptions and Calculations

Texas Electricity Savings Analysis											
	Total		2024	2025	2026	2027	2028	2029	2030	Notes	References
Cross-cutting data											
Housing units in Texas	11,869,072									This is for 2021, from https://www.census.gov/quickfacts/TX .	https://www.census.gov/quickfacts/TX
Households	10,239,341									For 2017-2021, from www.census.gov/quickfact/TX	
Annual growth in households	1.6%									Texas Demographic Center projects an average 1.6%/year population growth from 2020 to 2050.	https://demographics.texas.gov/Resources/publications/2019/20190128_PopProjectionsBrief.pdf
Percent multifamily	27.9%									From American Community Survey 2021 one-year estimates.	https://www.census.gov/programs-surveys/acs
Average T&D losses	5.34%									Average for Texas in 2021 (see table 10).	https://www.eia.gov/electricity/state/texas/
Electricity use/household		13,452								RECS 2020 electricity consumption per household in Texas	https://www.eia.gov/consumption/residential/data/2020/index.php?view=state#ce

Attic insulation/sealing and duct sealing

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of single family homes	7,269,932									RECS 2020 State Structural Characteristics table: Percentage of TX homes that are SF detached = 66%; in West South Central SF detached = 67.5%; in WSC SF detached + attached = 71%	https://www.eia.gov/consumption/residential/data/2020/index.php?view=state#hc. https://www.eia.gov/consumption/residential/data/2020/index.php?view=characteristics
Percent retrofit thru program	30%									48% of single family homes have insulation levels of R-19 or lower (ResStock); reach 60% of these through program	
Retrofits per year	2,180,980		109,049	218,098	327,147	436,196	436,196	436,196	218,098	5% in 1st year, 10% in 2nd year, 15% in 3rd, 20% years 4-6, 10% year 7	
Annual kWh saved per home	2173		2173	2173	2173	2173	2173	2173	2173	Used RECS 2020 and ResStock for data on average house size/configuration, existing insulation levels, and equipment types. Assume avg home 1737sf (RECS 2020), 63% of homes are one story and 37% two story (ResStock). Upgrade insulation in homes with existing attic/ceiling insulation less than R-19 to R-38. Calculated savings with TRM; used TRM "average condition" ducts for all climates duct sealing savings	RECS: https://www.eia.gov/consumption/residential/data/2020/state/xls/State%20Square%20Footage.xlsx ResStock: https://resstock.nrel.gov/dataviewer/building-characteristics/?datasetName=vizstock_resstock_tmy3_release_2022_1_by_state_view&locationId=TX
Summer kW saved per home	0.83		0.83	0.83	0.83	0.83	0.83	0.83	0.83	used TRM; 0.47 insulation + 0.36 duct sealing	
Winter kW saved per home	1.06		1.06	1.06	1.06	1.06	1.06	1.06	1.06	used TRM; 0.72 insulation + 0.33 duct sealing	
Annual GWh saved	4,992		250	749	1,498	2,496	3,495	4,493	4,992	Number of participants times savings per participant. Include savings from prior year participants and include T&D losses.	
Summer peak savings (MW)	1,907		95	286	572	953	1,335	1,716	1,907	Same method as for row above.	
Winter peak savings (MW)	2,435		122	365	731	1,218	1,705	2,192	2,435	Same method as for row above.	
Average cost per home			$ 3,500	$ 3,500	$ 3,500	$ 3,500	$ 3,500	$ 3,500	$ 3,500	Cost data from program evaluations, National Residential Efficiency Measures Database, and review of several online calculators. Assume contractor installed: $2250 for insulation and $1250 for duct sealing.	https://remdb.nrel.gov/
Average utility share			50%	50%	40%	40%	30%	30%	30%	50% is pretty common for contractor installed insulation and duct sealing; some utilities offer lower incentives for DIY. We start at 50%, but to reduce costs ramp down in years 3 and 5.	
Marketing and administrative costs as a percent of rebate costs			40%	30%	20%	20%	20%	20%	20%	LBL reports a range of 20-40%. We start at the high end and gradually decline to the low end as experience is gained and participation increases.	https://eta-publications.lbl.gov/sites/default/files/cose_final_report_20200429.pdf
Utility cost ($million)	3,420	1,568	$ 267	$ 496	$ 550	$ 733	$ 550	$ 550	$ 275		
Utility cost per home	1,695.00		2,450.00	2,275.00	1,680.00	1,680.00	1,260.00	1,260.00	1,260.00		

Replace electric furnaces with Energy Star HP

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of electric furnaces		3,400,000	3,400,000	3,400,000	3,400,000	3,400,000	3,400,000	3,400,000	3,400,000	From RECS 2009 (state-specific data not reported in RECS 2015). Do not have data on rate of growth so left level to be conservative.	https://www.eia.gov/consumption/residential/data/2009/index.php?view=characteristics
Percent of homes also with AC		95%	95%	95%	95%	95%	95%	95%	95%	In 2020, 95% of Texas homes had AC, including 83% of homes with central AC.	https://www.eia.gov/consumption/residential/data/2020/state/pdf/State%20Air%20Conditioning.pdf
Number replacements/year		215,333	215,333	215,333	215,333	215,333	215,333	215,333	215,333	Number of homes with electric furnaces times % with central AC divided by average 15 year life (from DOE).	
Percent who choose HP w/ incentive			20%	40%	60%	80%	80%	80%	80%	Ramp up to 80% since program covers incremental cost and there are benefits to homeowner in reduced energy costs and feeling that they are helping to address winter peaks.	
Number of participants	602,933		43,067	86,133	129,200	172,267	172,267	172,267	172,267		
Average kWh/home for space htg		1847	1847	1847	1847	1847	1847	1847	1847	For Texas from 2009 EIA RECS. Data at state level not available in 2015 RECS and this level of detail not released yet for 2020 RECS.	https://www.eia.gov/consumption/residential/data/2009/index.php?view=consumption
Heat pump COP		3.35	3.35	3.35	3.35	3.35	3.35	3.35	3.35	Based on new Energy Star HSPF2 for split systems.Energy Star should be a requirement for incentives. This is the minimum and most units will be a little higher so add 10%. HSPF ratings are based on a Houston climate so we further adjustment for performance in Texas relative to Houston, according to a study by FSEC. The FSEC study looked at performance in Fort Worth and Houston and we took the average.	Energy Star spec: https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%206.1%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20%28Rev.%20January%20%202022%29.pdf FSEC report: http://www.fsec.ucf.edu/en/publications/html/fsec-pf-413-04/
kWh saved/home space heating			551	551	551	551	551	551	551	Consumption divided by average annual COP. This underestimates fan energy savings as Energy Star 6.0 requires 2-speed or multispeed fans.	
Average kWh/home for space clg		4256	4256	4256	4256	4256	4256	4256	4256	For Texas from 2009 EIA RECS. Data at state level not available in 2015 RECS and this level of detail not released yet for 2020 RECS.	https://www.eia.gov/consumption/residential/data/2009/index.php?view=consumption
kWh saved/home space cooling		733	733	733	733	733	733	733	733	Based on new Energy Star SEER2 for split systems plus DOE estimate of fan energy savings in a hot-humid climate. Energy Star should be a requirement for incentives.	New DOE standard for HP is 14.3 SEER2, Energy Star spec is 15.2. Fan energy savings from DOE TSD, Table 7G.3.1. https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0098. Energy Star spec here: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.0%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20and%20Partner%20Commitments.pdf

Annual GWh saved	1,281		58	175	349	582	815	1,048	1,281	Number furnaces replaced per year * % participating * Savings per home / 1m (to convert to GWh) + savings from prior year (as heat pumps sold in earlier years are still saving energy). Add T&D losses.	
Winter kW/home with elec. Furnace		18	18	18	18	18	18	18	18	From Energy Use Calculator.com. This is about equivalent to a 60,000 Btu/hour heating load on the very coldest days.	https://energyusecalculator.com/electricity_furnace.htm
Heat pump COP at winter peak		2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	For a Goodman 4 ton HP at 17 F. Design conditions in Texas are for temperatures in the 20s F but given cold during storm Uri, we use 17 F.	https://www.goodmanmfg.com/pdfviewer.aspx?pdfurl=docs/librariesprovider6/default-document-library/ss-gszc16.pdf?view=true
Winter kW saved per HP			10.2	10.2	10.2	10.2	10.2	10.2	10.2	Heat pump COP * (electric furnace COP/heat pump COP)	
Winter peak savings (MW)			462	1,385	2,769	4,616	6,462	8,308	10,154	Number furnaces replaced per year * % participating * kW savings per home / 1000 (to convert to MW) + savings from prior year (as heat pumps sold in earlier years are still saving energy). Add T&D losses.	
Summer peak savings per HP		0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	Based on AC power draw times savings from improvement in SEER2 for Energy Star.	
Summer peak savings (MW)			4	12	23	39	55	70	86	Number furnaces replaced per year * % participating * kW savings per home / 1000 (to convert to MW) + savings from prior year (as heat pumps sold in earlier years are still saving energy). Add T&D losses.	
Average cost per home		$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$1440 difference in cost between an Energy Star heat pump and a minimum efficiency central AC, both based on 2023 DOE and EPA standards. Costs from DOE Techincal Support Document; in 2015$ and converted to 2023$ using Federal Resere GDP deflator through the end of 2022. These are for widespread sales so we round up by $95 to $2000 as heat pumps will often be a little more expensive than DOE estimates.	DOE TSD: https://www.regulations.gov/document/EERE-2014-BT-STD-0048-0098. Implcit price deflator from: https://fred.stlouisfed.org/series/GDPDEF.
Average utility share		25%	25%	25%	25%	25%	25%	25%	25%	For those eligible for IRA heat pump rebates (up to 150% of area median), the IRA rebate will fuly cover the incremental cost of a HP relative to an AC. We assume half the customers are eligible for IRA rebate. For those not eligible for IRA, 50% rebate (a very common utility incentive level). So if 50% do not receive a utility rebate and 50% receive a 50% of cost rebate, the average rebate is 25% of the cost.	
Marketing and administrative costs as a percent of rebate costs			40%	30%	20%	20%	20%	20%	20%	LBL reports a range of 20-40%. We start at the high end and gradually decline to the low end as experience is gained and participation increases.	https://eta-publications.lbl.gov/sites/default/files/cose_final_report_20200429.pdf
Utility cost ($million)	$ 302		$ 22	$ 43	$ 65	$ 86	$ 86	$ 86	$ 86	Number furnaces replaced per year * % participating * Cost per home * Utility share / 1m (to convert to $millions).	

Smart Thermostats	Total	2023	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of homes and apartments	10,239,341									From above.	
Percent with individual control	90%	90%	90%	90%	90%	90%	90%	90%	90%	According to ResStock 2022: 85.1% of TX homes have a central AC or heat pump; 6% have electric baseboard and less than 1% has no form of heating. There are also a few multifamily buildings without individual apartment thermostats. Per 2022 RECS, 87% of West South Central households have a thermostat: 12% smart; 39% programmable; 36% non-programmable	
Percent installed through program	30%		10%	15%	15%	15%	15%	15%	15%	Only included units with existing equipment.	
Installations per year	2,764,622		276,462	414,693	414,693	414,693	414,693	414,693	414,693	5% in 1st year, 10% in 2nd year, 20% years 3-5; 15% year 6, 10% year 7	
Average kWh/home for htg + AC	6103		6103	6103	6103	6103	6103	6103	6103	Used RECS from electric furnace analysis from above for consistency.	
Average kWh savings (%)	14%		14%	14%	14%	14%	14%	14%	14%	Used TRM to calculate deemed savings for installation with EXISTING equipment using TRM defaults of 3.7 tons; calculated 1433 kWh/yr savings or 23% -- seems too high. Adjusted to 14% savings to align with findings of program evaluations and range of savings in other TRMs	https://www.esource.com/system/files/esource-aceee-making-the-smart-home-work-for-you.pdf
Annual GWh saved	2,488		249	622	995	1,369	1,742	2,115	2,488	Number of participants times savings per participant. Include savings from prior year participants and include T&D losses.	
Summer peak savings/home (kW)	0.49		0.49	0.49	0.49	0.49	0.49	0.49	0.49	The TRM does not allow programs to account for demand savings from smart thermostats. Used peak savings values from 2021 study.	
Winter peak savings/home (kW)	1.10		1.10	1.10	1.10	1.10	1.10	1.10	1.10		
Summer peak savings (MW)	1,355		135	339	542	745	948	1,151	1,355	Number of participants times savings per participant. Include savings from prior year participants.	
Winter peak savings (MW)	3,029		303	757	1,212	1,666	2,120	2,575	3,029		
Average cost per home	$ 125		$ 125	$ 125	$ 125	$ 125	$ 125	$ 125	$ 125	Prices for 49 Energy Star connected thermostats range from $58-$380 with all major manufacturers offering products for less than $125; used $125 + $50 for program costs	https://choose.enervee.com/thermostats/?sortBy=price&filters=energy-star-10-connected-thermostats%3D1
Utility rebate cost (% of total cost)	40%	$50 rebate	40%	40%	40%	40%	40%	40%	40%	Austin Energy $30 rebate CenterPoint Energy $50 coupon	
Marketing and administrative costs as a percent of rebate costs	100%		100%	100%	100%	100%	100%	100%	100%		
Utility cost ($million)	$ 276		$ 27.6	$ 41.5	$ 41.5	$ 41.5	$ 41.5	$ 41.5	$ 41.5		

Heat pump water heaters

	Total	2023	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of electric water heaters	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5.56M electric WH in TX per 2020 RECS;	https://www.eia.gov/consumption/residential/data/2020/state/xls/State%20Water%20Heating.xlsx
Number of replacements per year	427,692		427,692	427,692	427,692	427,692	427,692	427,692	427,692	13 year life per last DOE standards rule	https://www.govinfo.gov/content/pkg/FR-2010-04-16/pdf/2010-
Percent who participate in program			4%	6%	8%	10%	12%	14%	16%		
HPWHs installed per year			17,108	25,662	34,215	42,769	51,323	59,877	68,431		
Total HPWHs installed	299,385		17,108	42,769	76,985	119,754	171,077	230,954	299,385		
Deemed annual kWh savings per HPWH	2017		2017	2017	2017	2017	2017	2017	2017	TRM values weighted by TX climate zone population and mix of product sizes (40 gallon 45%, 50 gallon 50%, 75 gallon 5%). Savings for minimum Energy Star level over minimum standard per TRM	see detailed analysis here: https://aceeeorg-my.sharepoint.com/:x:/r/personal/jamann_aceee_org/Documents/My%20Documents/ACEEE/Residential%20retrofits/001%20-%202023%20REV%20jen%20analysis%20for%20TX%20EE%20and%20DR%20project.xlsx?d=wc1a943b79bf54c02b87bca6c4914ee37&csf=1&w
New annual savings from HPWHs installed (GWh)			36	55	73	91	109	127	145	# heat pumps installed * deemed annual kWh energy savings / 1000000 (to convert to GWh). Add T&D losses.	
Total annual savings by end of year (GWh)	636		36	91	164	254	363	491	636	cumulative savings	
Deemed summer demand savings (kW) per HPWH	0.22		0.22	0.22	0.22	0.22	0.22	0.22	0.22	TRM values weighted by TX climate zone population and mix of product sizes (40 gallon 45%, 50 gallon 50%, 75 gallon 5%). Savings for minimum Energy Star level over minimum standard per TRM	
Deemed winter demand savings (kW) per HPWH	0.38		0.38	0.38	0.38	0.38	0.38	0.38	0.38	TRM values weighted by TX climate zone population and mix of product sizes (40 gallon 45%, 50 gallon 50%, 75 gallon 5%). Savings for minimum Energy Star level over minimum standard per TRM	
Total summer demand savings (MW) by year 7	222		4.0	13.9	31.7	59.5	99.1	152.6	222.0	kW deemed summer savings * number of units, /1000 to convert to MW	
Total winter demand savings (MW) by year 7	383		6.8	24.0	54.8	102.7	171.2	263.7	383.5	kW deemed winter savings * number of units, /1000 to convert to MW	
Average cost per home (incremental cost of Energy Star HPWH vs standard compliant)	$ 630		$ 630	$ 630	$ 630	$ 630	$ 630	$ 630	$ 630	Incremental installed cost of Energy Star HPWH relative to standard compliant unit per DOE Preliminary TSD, March 2022, Table 8.2.8. $633 for 40 and 50 gallon; $33 for units over 55 gallons	https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0018
Utility rebate cost ($million)		$300	$ 3.8	$ 5.8	$ 7.7	$ 9.6	$ 11.5	$ 13.5	$ 15.4	Austin Energy offers a HPWH rebate of $800. SWEPCO offers $500 - $1,150 Farmers Electric Cooperative offers $300 HEEHR will cover 100% or 50% of costs for low- and moderate-income households. Assume 25% of customers are eligible for full federal rebate.	
Marketing and administrative costs as a percent of rebate costs			40%	30%	20%	20%	20%	20%	20%	LBL reports a range of 20-40%. We start at the high end and gradually decline to the low end as experience is gained and participation increases.	https://eta-publications.lbl.gov/sites/default/files/cose_final_report_20200429.pdf
Utility cost ($million)	$ 82		$ 5.4	$ 7.5	$ 9.2	$ 11.5	$ 13.9	$ 16.2	$ 18.5		

Central AC/electric heating demand response

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Percent of homes with central AC		85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	According to ResStock 2022: 85.1% of TX homes have a central AC or heat pump	
Percent of homes with central AC and electric furnace or heat pump		38.0%	38.0%	38.0%	38.0%	38.0%	38.0%	38.0%	38.0%	Per RECS 2020, 19% of TX homes have heat pumps and 19% have electric furnaces	
Summer demand savings per home (kW)		1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	Per TRM, 1.45 kW/home per load management event. This is close to experience from San Antonio using 33% and 50% cycling options with a Whisker Labs cycling pattern for 1.12 kW.	https://www.sanantonio.gov/Portals/0/Files/Sustainability/STEP/CPS-FY2019.pdf
Winter demand savings per home (kW)		1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	Per various potential studies and reports on actual winter demand response programs in FL and AL, and data in TRM showing savings ranging from 0.8 kW/home to 1.87 kW/home for winter heating DR.	
Participation in cycling program			10%	15%	20%	25%	30%	30%	30%	10-30% from Faruqui recommendations to PUCT in 2012 based on best programs around the US.	https://brattlefiles.blob.core.windows.net/files/6566_direct_load_control_of_residential_air_conditioners_in_texas_faruqui_puct_oct_25_2012.pdf
Number of participants (summer)			870,344	1,305,516	1,740,688	2,175,860	2,611,032	2,611,032	2,611,032		
Number of participants (winter)			389,095	583,642	778,190	972,737	1,167,285	1,167,285	1,167,285		
Summer peak savings (MW)	3,988	-	1,329	1,994	2,659	3,323	3,988	3,988	3,988	Multiply above rows, add T&D losses. Note: This includes Austin and San Antonio who already have programs.	
Winter peak savings (MW)	1,476		492	738	984	1,230	1,476	1,476	1,476	same as above	
Incentive per year per home (new enrollments plus annual summer participation)		$115	$115	$58	$51	$47	$44	$30	$30	We start with Austin Energy and CPS provide an $85 incentive to enroll; CPS also provides $30 incentive each summer for participating in load management events.	
Incentive per year for winter participation		$20	$20	$20	$20	$20	$20	$20	$20	$20 per winter season for participation	
Utility cost ($million)	$ 1,063	$ -	$ 150	$ 122	$ 146	$ 169	$ 193	$ 141	$ 141	Add 20% for administrative and marketing costs.	E-Source DSM Insights database.

Water heater demand response

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of electric water heaters		5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	5,560,000	From HPWH analysis	
Percent participating in DR			5%	10%	20%	25%	30%	35%	40%	Brattle 2016 modeling assumes 20% participation, but notes examples up to 40-50% for other direct load control programs. We gradually ramp up to 40%.	2016 Brattle Group report for NRDC, NRECA and PLMA https://rpsc.energy.gov/tech-solutions/technologies/heat-pump-water-heater/resources/hidden-battery-opportunities-electric-water-heating
Participants			278,000	556,000	1,112,000	1,390,000	1,668,000	1,946,000	2,224,000		
Avg. summer kw peak reduction / participant (ERWH)			0.40	0.40	0.40	0.40	0.40	0.40	0.40	PJM case study finds 0.36 kW. HECO paper found 0.321 kW Fort Collins Utilities reports: 0.3 to 0.5 kW	PJM case study: https://plma.memberclicks.net/assets/resources/Guidehouse%20Insights_ArmadaPowerWhitePaper.pdf Hawaii Electric Company (HECO): https://www.iepec.org/wp-content/uploads/2022/11/Stewart_James_paper.pdf Fort Collins Utilities: https://www.aceee.org/sites/default/files/publications/researchreports/u1906.pdf
Avg. summer kw peak reduction /participant (HPWH)			0.20	0.20	0.20	0.20	0.20	0.20	0.20	Currently using above kW demand reduction/2 for HPWH	
Avg. winter kw peak reduction /participant (ERWH)			0.50	0.50	0.50	0.50	0.50	0.50	0.50	BPA pilot for CTA-2045	
Avg. winter kw peak reduction /participant (HPWH)			0.25	0.25	0.25	0.25	0.25	0.25	0.25		
Summer peak savings (MW)	904		116	232	462	574	685	795	904	Adjusted for ~1% of installed market HPWH (<1% as of 2017 per PNNL report). Assume this grows to 2% by fifth year. 2% 2020 market penetration estimated by Energy Star Unit Shipment & Market Penetration analysis. Added T&D losses.	PNNL Report: : https://rpsc.energy.gov/tech-solutions/sites/default/files/resources/attachments/ECEEE_EEDAL_Paper-159_US-HPWH-Mkt-Transformation_7-21-2017%5B1%5D.pdf ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 2020 Summary: https://www.energystar.gov/sites/default/files/asset/document/2020%20USD%20Summary%20Report_Lighting%20%20EVSE%20Update.pdf
Winter peak savings (MW)	1,130		145	290	577	717	857	994	1,130		
Per home - device cost	$ 50									Quick scan of online prices suggests control devices run $70-$200, with ~$150 being common at retail. We estimate utilities can buy in bulk at half this cost.	
Per home - one-time $25 incentive	$ 25										
Incentive per home - $25 annually to allow device management	$25									Duke EnergyWise (SC) water heater DLC and HP DLC program: Incentive is $25 to sign up, $25 annually to remain	

Capitalized costs of control device			$ 1.5	$ 3.1	$ 6.0	$ 7.4	$ 8.7	$ 9.9	$ 11.0	Capitalized for 15 years at 8% rate of return. Manufacturers are increasingly incorporating controllers into new water heaters. We assume the number of units with on-board controllers grows from 1% in year 1 to 30% in year 7.	
One-time start up cost			$ 6.6	$ 6.6	$ 12.5	$ 5.9	$ 5.6	$ 5.2	$ 4.9		
Annual customer payments			$ 7.0	$ 13.9	$ 27.8	$ 34.8	$ 41.7	$ 48.7	$ 55.6		
Administration costs			$ 3.0	$ 4.7	$ 9.3	$ 9.6	$ 11.2	$ 12.8	$ 14.3	Add 20% for administrative and marketing costs.	E-Source DSM Insights database.
Utility cost ($million)	$ 389		$ 18	$ 28	$ 56	$ 58	$ 67	$ 77	$ 86	Cost of control device plus one-time incentive ($25) plus $25/year to remain, /1M	

EV charging demand response

	Total	2023	2024	2025	2026	2027	2028	2029	2030	Notes	References
Number of EVs in Texas		190,205	305,890	421,575	537,260	652,945	768,630	884,315	1,000,000	ERCOT estimates there will be 1M EVs on the road in TX by 2028; TX DMV estimates the state will reach 1M EVs by 2031. We split the difference and assume 1M vehicles in 2030. Texas EV Registration Dashboard reports 190,205 EVs registered as of 4/25/23. We interpolate from current 2023 registration to 1M in 2030.	ERCOT and TX DMV estimates reported in Texas Electric Vehicle Infrastructure Plan 7/8/22 from TX DOT, TX CEQ, and TX SECO: https://cleantechnica.com/files/2022/07/TexasElectricVehicleChargingPlan.pdf TX Electric Vehicle Registration Tool: https://app.powerbi.com/view?r=eyJrIjoiYTRlY2M2MTctZDYwZC00MDNjLThkZDMtZjY5N2Y1YzlkNzA5IiwidCI6IjJmNWU3ZWJjLTIyYjAtNGZiZS05MzRjLWFhYmRkYjRlMjliMSIsImMiOjN9
Avg. kW curtailed/participant (no seasonal difference per literature)	Level 1: 1.9 kW Level 2: 6.6 kW	5.425	5.425	5.425	5.425	5.425	5.425	5.425	5.425	Multiple sources report 1-3kW for Level 1 chargers and 6-19 for Level 2 chargers. DOE's Alternative Fuels Data Center assumes 1.9kW for Level 1 and 6.6kW for Level 2 residential chargers. These values align with CA IOUs study of customer loads with TOU rates for EV. Recent JD Power study estimates more than 75% of drivers have Level 2 chargers at home.	https://afdc.energy.gov/fuels/electricity_infrastructure.html
Percent participating in DR program			50%	65%	70%	75%	75%	75%	75%	SEPA survey of EV drivers: 65% of those with access to Time-of-Use rate programs use them (75% in CA, 48% elsewhere in the nation), with ~95-100% off-peak charging 87% of the time. Same survey suggests 72% of non-enrolled EV drivers are willing to charge off-peak given incentives and convenient program structure. Assuming that an appropriately designed direct load control program could capture similar rates of participation. CA IOUs analysis of 2021 data show growing participation in EV TOU rates with average use of off-peak and super off-peak rates for EV charging ranging from ~70-90%	SEPA 2019: https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/
Cumulative participants each year			152,945	274,024	376,082	489,709	576,473	663,236	750,000		
New participants each year			152,945	121,079	255,003	234,706	341,767	321,469	428,531		
Summer peak demand savings (MW)	4,286		874	1,566	2,149	2,799	3,294	3,790	4,286	Participants * impact/participant. Add T&D losses.	
Winter peak demand savings (MW)	4,286		874	1,566	2,149	2,799	3,294	3,790	4,286	Same as above.	
kWh/100 miles			36	36	36	36	36	36	36	kWh/100 miles for recent model years ranges from the low 20's for smaller vehicles to over 50 for trucks and larger SUVs. Based on popularity of larger vehicles in Texas, used this value averaging most popular sedans, trucks, and SUVs based on EPA/DOE data from fueleconomy.gov	https://www.fueleconomy.gov/feg/PowerSearch.do?action=PowerSearch&year1=2022&year2=2024&minmsrpsel=0&maxmsrpsel=0&city=0&highway=0&combined=0&YearSel=2022-2024&MakeSel=&MarClassSel=&FuelTypeSel=&VehTypeSel=&TranySel=&DriveTypeSel=&CylindersSel=&MpgSel=&sortBy=&Units=&url=SearchServlet&opt=new&minmsrp=0&maxmsrp=0&minmpg=&maxmpg=&sCharge=&tCharge=&startstop=&cylDeact=&rowLimit=50
Miles per year		10,000	10,700	11,400	12,100	12,800	13,500	13,500	13,500	More recent and new model EVs driven much like current gas vehicles. Assume gradually ramps from 10k to current average for fuel vehicles.	
Annual kwh/car			3,852	4,104	4,356	4,608	4,860	4,860	4,860	Multiply above 2 rows	
Percent charging offpeak			80%	80%	80%	80%	80%	80%	80%	Based on SEPA and CA IOU studies	
Per kWh off-peak discount			$ 0.06	$ 0.06	$ 0.06	$ 0.042	$ 0.042	$ 0.024	$ 0.024	CPS energy offers $125 bill credit to incentivize participation in a Time-of-Use program (FlexEV Off-Peak Rewards) (agree to charging outside of peak hours for the majority of the month, with a $10 bill credit when you charge no more than twice during peak). Austin Energy EV360 charging pilot used an unsubsidized (self-sustaining) TOU rate design to push EV demand to off-peak hours (outside 2-7PM). We propose discounts for off-peak charging starting at 50% per kWh ramping down to 35% after 3 years, and then to 20% for the final 2 years of the program.	CPS programs: https://cpsenergy.com/en/about-us/programs-services/electric-vehicles/ev-charging-solutions.html Austin Energy: https://austinenergy.com/wcm/connect/b216f45c-0dea-4184-9e3a-6f5178dd5112/ResourcePlanningStudies-EV-Whitepaper.pdf?MOD=AJPERES&CVID=mQosOPJ
Annual value of discount/car			185	197	209	155	163	93	93	Miles * discount	
Utility cost ($million)	$ 380		34	65	90	87	104	68	77	Add 20% for administration and marketing in early years, declining to 10% by fifth year	E-Source DSM Insights database for the 20%; ACEEE estimate for the gradual decline.

Monitoring-Based Commissioning

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Comm'l building million sf WSC	11,580		11,770	11,802	11,834	11,867	11,899	11,931	11,964	From 2018 CBECS table b5	EIA, CBECS 2018
% in buildings > 50,000 sf	47%		47%	47%	47%	47%	47%	47%	47%	Same as above	Same as above
Texas percentage of above	73%		73%	73%	73%	73%	73%	73%	73%	From EIA for 2021	https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_use_es.html&sid=US
Annual growth rate	0.27%		0.27%	0.27%	0.27%	0.27%	0.27%	0.27%	0.27%	Based on growth in commercial building floor area in WSC since 2012. This may be low for Texas but we use as we could not find better data.	EIA, CBECS 2012 and 2018
kWh/sf	17.0		17.0	17.0	17.0	17.0	17.0	17.0	17.0	From 2018 CBECS table C21 for WSC for buildings 100k sf and larger	EIA, CBECS 2018
Base GWh of targeted buildings			69,024	69,212	69,400	69,589	69,778	69,968	70,159		
Average % savings	9%		9%	9%	9%	9%	9%	9%	9%	Ruffin et al. find 11% avg across 592 buildings; LBL finds 9% in second year. NYSERDA RTEM program averages 8.2%. We average the three.	Ruffin et al. 2021, Kramer et al. 2020, NYSERDA 2023
Measure life	8									From evaluation of Illinois 2021 program	Guidehouse 2022
Participation rate			3%	6%	9%	12%	15%	18%	21%		
Participating sf -- 1st year (m sf)			121.8	122.5	122.5	122.6	122.7	122.9	123.1		
Recurring	735		-	121.8	244.3	366.8	489.4	612.2	735.1		
Total annual GWh savings			195	378	563	750	937	1,125	1,315	Assume 1/16 of prior years savings lost each year, in line with measure life	
Hours per year	8,760										
MW savings if evenly distributed			22.2	43.2	64.3	85.6	107.0	128.5	150.1	Savings if kWh savings distributed over 8760 hours/yr	
Summer peak savings (MW)			44.4	86.3	128.7	171.2	213.9	256.9	300.1	MW savings if distributed over half the hours in a year. This seems in line with the limited available data for summer peak savings which on a percentage basis is similar to the	Ruffin et al. 2021, Kramer et al. 2020
Winter peak savings (MW)			18.5	36.0	53.6	71.3	89.1	107.0	125.0	Winter peak savings seem to be similar if electric heat but much lower if gas heat. We take summer peak estimate and multiply by the percent of floor area in ESC that uses electric	Relative floor area from EIA CBECS 2018 for East South Central region.
Utility program cost/sf	0.25									Used average incentive from NYSERDA RTEM program. This covers an average of 32% of the cost -- customer will also have to contribute. Texas A&M found $.42-1.30/sf on recent	From NYSERDA dashboard
Utility program cost	214.5		30.5	30.6	30.6	30.7	30.7	30.7	30.8		

Small C&I

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Comm'l building million sf WSC	11,580		11,770	11,802	11,834	11,867	11,899	11,931	11,964	From 2018 CBECS table b5	EIA, CBECS 2018
% in buildings < 25,000 sf	38%		38%	38%	38%	38%	38%	38%	38%	Same as above	Same as above
Texas percentage of above	73%		73%	73%	73%	73%	73%	73%	73%	From EIA for 2021	https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_use_es.html&sid=US
Annual growth rate	0.27%		0.27%	0.27%	0.27%	0.27%	0.27%	0.27%	0.27%	Based on growth in commercial building floor area in WSC since 2012. This may be low for Texas but we use as we could not find better data.	EIA, CBECS 2012 and 2018
Average size of participating buildings	10,000									From CBECS for WSC, average size a little below 10,000 sf but larger buildings a little more likely to participate	EIA, CBECS 2018
Number of targeted buildings			328,540	329,434	330,330	331,229	332,130	333,034	333,940	From 2018 CBECS table C21 for WSC for buildings 100k sf and larger	EIA, CBECS 2018
Annual participation rate			1%	2%	3%	5%	5%	5%	5%		
Number of participating buildings	86,301		3,285	6,589	9,910	16,561	16,607	16,652	16,697		
kWh savings/building	35,376									From Austin program	Austin 2022
Average measure life	10									From Austin program	Austin 2022
Incremental annual savings (GWh)			116	233	351	586	587	589	591		
Total annual GWh savings			116	343	677	1,229	1,755	2,256	2,734	Assume 5% of prior year savings lost each year, in line with measure life	
Ratio kW/kWh	0.000393815									From Austin program	Austin 2022
Total annual MW savings											
Summer peak			46	135	267	484	691	889	1,077		
Winter peak			31	90	178	323	461	592	718	ACEEE estimate that in winter 60% of lights and HVAC will be functioning at morning peak, vs. about 90% for afternoon summer peak	
Utility cost/customer	$ 10,151									From Austin program	Austin 2022
Total utility cost (million $)	876.1		33.4	66.9	100.6	168.1	168.6	169.0	169.5		

Low-Income Kits

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Households < poverty level	14.20%									This is for persons but apply to households	https://www.census.gov/quickfacts/fact/table/TX/RHI125221
Adjustment for 200% of poverty	2.38									Ratio for the U.S.	https://www.census.gov/data/tables/time-series/demo/income-poverty/cps-pov/pov-01.html
Households <200% poverty level			3,459,485	3,514,837	3,571,074	3,628,211	3,686,263	3,745,243	3,805,167		
Penetration			10%	20%	30%	40%	50%				
Number of participants	1,791,522		345,948	357,019	357,107	362,821	368,626		-		
kWh saved/kit	136									Austin evaluation estimates 130 for kits distributed via schools, CPS evaluation estimates 142. We use average.	Austin 2022, CPS 2022
Measure life	10									From Austin evaluation.	Austin 2022.
Total annual GWh savings			47.0	140.3	279.0	462.4	690.0	655.5	622.7	Assume 5%/yr lost, in line with measure life	
Ratio of summer kW/kWh savings	0.000108									From Austin and CPS evaluations. We use average.	Austin 2022, CPS 2022
Avg. summer coincidence factor	0.053400									For GSL LED bulbs, average coincidence factor for the five zones used in PUCT TRM	PUCT 2022 (2023 TRM)
Avg. winter coincidence factor	0.265400									Same as above. Showers are also more common in the morning when winter peak generally occurs.	Same as above
Total annual MW savings											
Summer peak			5	15	30	50	75	71	67	From Austin and CPS evaluations. We use average.	Austin 2022, CPS 2022
Winter peak			25	75	150	248	370	352	334		
Cost/kit	$31									From CPS evaluation.	CPS 2022
Program costs/kit	$16									Estimate based on Austin and Xcel CO data	Austin 2022, Xcel 2022
Total ($million)	$47		16.1	16.3	16.6	16.9	17.1			Costs calculated based on new participants each year	

Low-Income Single-Family

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Households <200% poverty level			3,459,485	3,514,837	3,571,074	3,628,211	3,686,263	3,745,243	3,805,167	From Kit program above	
% SF	57%									Includes owner-occupied and rental	TEPRI 2019
Target mkt -- energy bills > avg			988,375	1,004,189	1,020,256	1,036,580	1,053,165	1,070,016	1,087,136		
Penetration			1.0%	3%	5%	5%	5%	5%	5%	ACEEE estimated ramp-up	
Number homes served	303,367		9,884	30,126	51,013	51,829	52,658	53,501	54,357		
kWh saved per home	3948									From CPS 2019 program; 2021 program very similar	CPS 2022
Avg. measure life	15									From Austin	Austin 2022
GWh saved current year partic.			39.0	118.9	201.4	204.6	207.9	211.2	214.6		
GWH saved including prior years			39	157	353	546	735	922	1,106	Assume 1/30 of prior year savings lost each year, in line with measure life	
Ratio of summer kW/kWh savings	0.000639									Average of Austin and CPS data	Austin 2022, CPS 2022
Summer peak kW factor	3.46									Used air infiltration as a proxy. This is the kW savings per CFM50 of infiltration reduction, averaging five zones	PUCT 2022 (2023 TRM)
Winter peak kW factor	5.16									Same as above, but giving equal weight to electric resistance and heat pumps.	PUCT 2022 (2023 TRM)
MW saved											
Summer peak			25	100	225	349	470	589	707	Used summer kW/kWh savings factor from above.	
Winter peak			37	150	337	521	702	880	1,056	Used ratio of summer peak to winter peak factors from rows above.	
Utility cost/home	5392									From CPS 2019 program	CPS 2022
Utility cost ($million)	1,635.8		53	162	275	279	284	288	293		

Low-Income Multifamily

	Total	2023 (base)	2024	2025	2026	2027	2028	2029	2030	Notes	References
Households <200% poverty level			988,375	1,004,189	1,020,256	1,036,580	1,053,165	1,070,016	1,087,136	From Kit program above	
% MF	43%									Includes owner-occupied and rental	TEPRI 2019
Penetration			1.0%	3%	5%	5%	5%	5%	5%	ACEEE estimated ramp-up	
Number of apartments served	130,023		4,236	12,912	21,864	22,214	22,569	22,930	23,297		
kWh saved per apartment	2358									From ComEd 2019 program	ComEd 2022
Measure life	15									From Austin program	Austin 2022
GWh saved current year partic.			10.0	30.4	51.6	52.4	53.2	54.1	54.9	From CPS 2019 program; 2021 program very similar	CPS 2022
GWH saved including prior years			10	40	90	140	188	236	283	Assume 1/30 of prior year savings lost each year, in line with measure life	
Ratio of summer kW/kWh savings	0.000337									For Austin MF program	Austin 2022
Summer peak kW factor	3.46									Used air infiltration as a proxy. This is the kW savings per CFM50 of infiltration reduction, averaging five zones	PUCT 2022 (2023 TRM)
Winter peak kW factor	5.16									Same as above, but giving equal weight to electric resistance and heat pumps.	PUCT 2022 (2023 TRM)
MW saved											
Summer peak			3	14	30	47	63	80	95	Used summer kW/kWh savings factor from above.	
Winter peak			5	20	45	70	95	119	143	Used ratio of summer peak to winter peak factors from rows above.	
Utility cost/apartment	1029									From ComEd 2019 program	ComEd 2022
Utility cost ($million)	133.8		4	13	22	23	23	24	24		