2019

Electrification of Heating in the Texas Residential Sector

REPORT PREPARED FOR PECAN STREET INC.

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Executive Summary

In 2018, 30% of Texas electric power was generated by carbon-free sources, with nearly 20% of power coming from West Texas wind farms. Wind and solar power markets continue to grow in the state, with wind energy alone projected to provide nearly 25% of ERCOT's 2019 generation capacity, while electricity rates remain some of the lowest in the nation. Electrification of the building sector represents an opportunity to significantly reduce greenhouse gas emissions while saving families money on their utility bills.

To understand the effects of residential heating electrification under various technology and climate scenarios, Pecan Street Inc. commissioned leading research organization IdeaSmiths to analyze the grid system impacts of electrifying single-family residential heating in Texas.

Using the fuel mix for Texas in 2017, the analysis found that electrification of heating in the Texas single-family residential sector would likely result in carbon dioxide emissions reductions of about 3.5 million metric tons and nitrogen oxide emissions reductions of about 2,700 metric tons if all gas furnaces are replaced by mid-efficiency heat pumps. High-efficiency heat pump deployment resulted in emission reductions nearly five times greater. Total sulfur dioxide emissions increased in the mid-efficiency scenario, but decreased in the high-efficiency scenarios. These emission reductions are likely conservative because as the ERCOT grid becomes cleaner, emissions associated with the electrification of heat will also fall. Although peak demand is often associated with higher emission intensities because of the use of inefficient peaking power plants, new winter peak demands in the mornings are more aligned with times of strong wind output.

Using currently available technology, electrification of residential heating would likely result in a winter peak that is larger than the current summer peak for the ERCOT grid. Depending on the efficiency of heat pump used to electrify heating, total electricity consumption could increase or decrease. Electrification scenarios with high efficiency heat pumps see a large overall reduction in total electricity use due to more efficient cooling in the summer. This could result in hundreds of dollars of savings per household at current natural gas and electricity prices in Texas.

Additionally, reduced consumption of natural gas for heating during the winter has benefits outside of emissions reductions and utility bill savings. The reduced demand for natural gas at the distribution level frees up the natural gas pipeline network to devote more fuel to efficient, relatively low-carbon emitting natural gas power plants. On the demand side, it reduces the likelihood of carbon monoxide leaks in homes that cause serious safety issues to the homes' occupants.

A cash flow analysis of an average 1600 square foot home in Austin, TX modeled using NREL's ResStock Analysis Tool yields savings in utility bills and energy-related costs for 3 out of 4 scenarios where a natural gas furnace is replaced by an electrified heat pump.

Introduction

The push to decarbonize the world's economies has led to policy discussions on fully electrifying the residential sector [1]. This involves completely transitioning any appliances that use on-site fuels (e.g. propane, natural gas, fuel oil) to appliances that instead use electricity. For space heating, this transition includes replacing fossil fuel powered furnaces with electric heaters such as an ASHP (air-source heat pump) or a MSHP (mini-split heat pump). Analysis has shown transitioning to electric devices can reduce emissions, even using conservative adoption models [2]. However, some researchers predict that carbon emission reductions from electrifying residential households are as small as 1 – 1.5% (between 65 and 93 million metric tons of CO_2)[1].

Studies indicate that high adoption of electrified space heating has the potential to significantly shift total grid load shapes and change which season some grid's annual peak demand occurs [3], [4]. This can result in higher emissions from the electric grid if fossil-fueled power plants are used to meet the increased load and ramping needs. If renewables are used to meet the increased capacity, other problems occur, such as the need to overbuild or incorporate energy storage, potentially increasing costs. A recent analysis of the adoption of electrified heating in California paired with heavy implementation of solar PV resulted in high amounts of curtailed renewable generation equaling nearly 100% of peak demand [4].

Heat pump performance in cold climates can also be an issue when trying to electrify the residential sector. Subject to the laws of thermodynamics, air-source heat pumps perform worse as the outdoor temperature decreases. For example, an outdoor temperature drop from 47 degrees Fahrenheit (8.33 ^{0}C) to 17 degrees Fahrenheit (-8.33 ^{0}C) can cause the coefficient of performance (a measure of efficiency) to drop around 36% for a standard heat pump [5]. The capacity (amount of delivered heat) of heat pumps also declines as the outdoor temperature drops. Mini-split heat pumps are better performing in part because they are ductless—ducts can account for more than 30% of energy consumption for space conditioning [6]. They can also be more efficient in low temperature environments as some provide heating down to negative 15 degrees Fahrenheit (-9.44 ^{0}C) [7]. However, multiple mini-split heat pumps are often, but not always, required for homeowners that wish for more than one room to be conditioned. This can cause the cost of an MSHP conditioned home to increase quickly.

Natural gas furnaces do not typically suffer from the same performance degradation based on outdoor air temperature as heat pumps. They also do not directly contribute to increasing the electrical load on the grid[1] (it is likely there are indirect effects due to electric natural gas pumps used in the gas transmission system). But studies have shown that the electrification of fossil-fueled appliances like natural gas space heaters is a crucial component of decarbonization [8]. Natural gas emits multiple greenhouse gases when combusted to

[1] Both heat pumps and natural gas furnaces use electrically driven fans to move conditioned air in a space, so we do not consider that in this analysis.

generate heat. For every 1000 kBtu of natural gas combusted, NO_x (0.092 lbs.), CO_2 (117 lbs.), and SO_2 (0.00059 lbs.) are emitted [9]. Natural gas furnaces also emit trace amounts of carbon monoxide, a potentially lethal gas [10].

The Texas residential sector consists of approximately 7.7 million homes, primarily heated by natural gas [11]. Currently, for space heating, the sector consumes 9 TWh of electricity and 31 TWh equivalent of natural gas (105 trillion BTU) [12]. Air conditioning, which almost exclusively uses electricity, consumes 35 TWh of electricity per year [12]. If the entire Texas residential heating sector were to be fully electrified, more than 75% of space heating energy consumption would need to be shifted to electricity.

Multiple studies have explored the adoption of heat pumps as part of the path to electrify the residential sector. Models developed to quantify the increase in energy consumption from nationwide adoption of heat pumps in the United Kingdom showed a peak net-demand increase by 100% [13]. A study of Los Angeles county showed that heavy electrification resulted in an increase of electricity demand by 87% [14]. Although these climates are very different, they yield similar results. Texas is differentiated from LA and the UK by its potential to be extremely hot (100+ degrees Fahrenheit for multiple days) and extremely cold (many regions of the state can face multiple days of freezing temperatures). Both the UK and LA studies use an energy model based on creating archetypes of houses and scaling each archetype's energy demand to reflect their respective region's residential sector energy demand.

In this analysis, we follow a similar methodology through the use of NREL's ResStock tool [15]. ResStock utilizes the industry-standard EnergyPlus™ building energy simulation engine and housing stock parameters for 17 locations around the state of Texas. ResStock probabilistically samples housing parameters based on weights assigned to each parameter as a function of the location to develop unique housing archetypes. Each archetype is simulated through the EnergyPlus™ engine to calculate its energy usage data. From these data, we can analyze the energy consumption and peak energy demand in Texas if every fossil fueled space heater was replaced by an electricity powered heat pump.

Methodology

The core methodology for energy modeling in this report utilizes NREL's ResStock Analysis tool [16]. ResStock statistically samples housing stock parameter data for 17 locations around Texas and uses weather files to simulate a year of energy usage through the EnergyPlus™ engine. Figure 1 shows a visual description of the analysis process.

Building-level energy simulations utilize weather files to both designate location and test a building's performance against different climates. Because this analysis sought to assess the impact of electrified heating on peak power demand from single family detached homes in ERCOT, actual year weather files are utilized in the model. Different heat pump efficiency parameters (e.g. HSPF value) were also tested to assess their impact on peak power demand and overall energy use. These energy usage data are then analyzed to find how Texas's residential electricity demand would change in the case of replacing all gas or propane furnaces in the state with electric heat pumps.

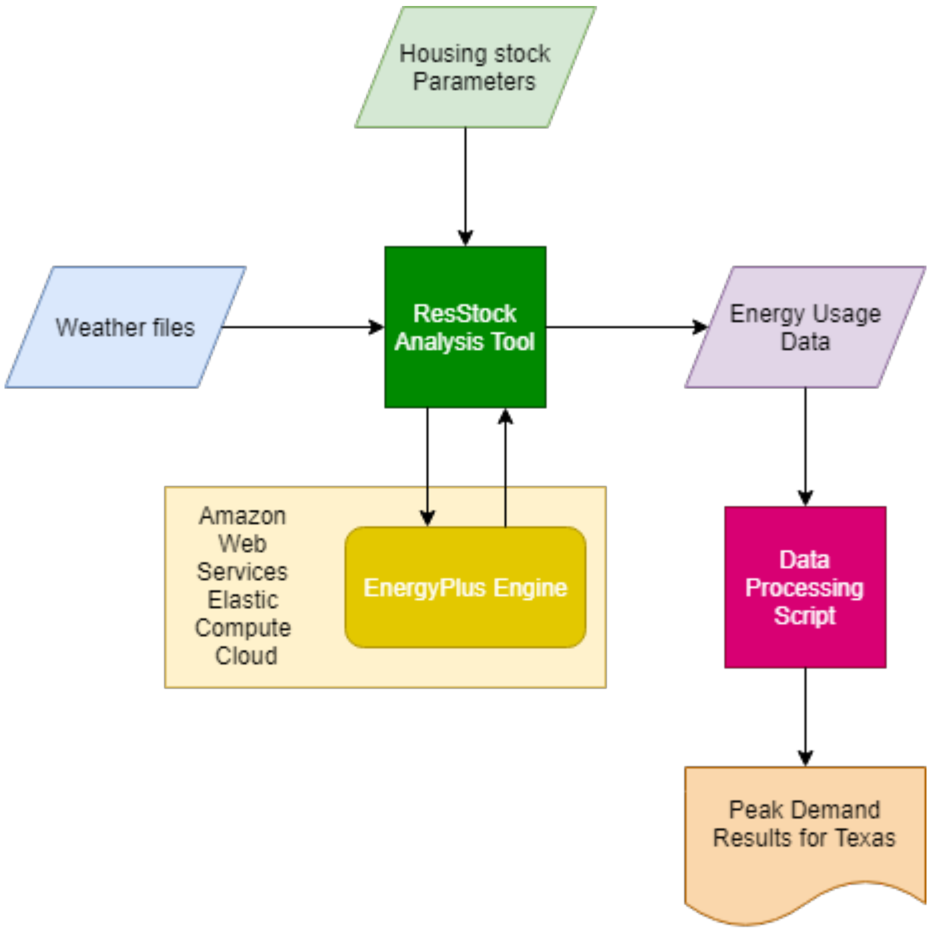

Figure 1. Energy model methodology centered around the ResStock Analysis Tool.

ResStock

Each simulation created by the ResStock analysis tool generates a single-family detached home from statistically sampling a residential housing parameter space [18]. The parameter space uses housing stock data from 11 different sources to determine probability distributions for each residential housing parameter as a function of location [16]. A complete list of parameters can be found in the Appendix.

The parameters for the home simulations are input into the EnergyPlus™ simulation engine [19]. These simulations are computed via Amazon Web Services Elastic Compute Cloud (AWS EC2). Each ResStock run used in this analysis uses 9,000 simulations to represent the single-family detached residential sector of ERCOT, about 5.9 million homes. This results in an approximate simulation weight of 650 homes per simulation. Each simulation also creates a business-as-usual case that represents the current heating profile of the single-family detached residential sector.

Table 1 shows the simulations scenarios completed for this report. Each scenario includes the type of heat pump chosen as replacement for gas and propane furnaces and which weather file package was used as an input. Simulations 5 and 6 reflect a 60%/40% blend of each respective heat pump to simulate a middle adoption pathway.

Table 1. Model scenario matrix showing the different scenarios considered in this analysis, ASHP = air-source heat pump, MSHP = mini-split heat pump, SEER = seasonal energy efficiency ratio, HSPF = heating season performance factor.

Simulation	Heat Pump type	Weather File
1	ASHP, SEER 14, 8.2 HSPF, ducted	2011 AMY
2	ASHP, SEER 14, 8.2 HSPF, ducted	TMY
3	MSHP, SEER 29.3, 14 HSPF, ductless	2011 AMY
4	MSHP, SEER 29.3, 14 HSPF, ductless	TMY
5	Blend: 60% ASHP 40% MSHP	2011 AMY
6	Blend: 60% ASHP 40% MSHP	TMY

Data Processing

To process the data output by ResStock we collect the hourly usage data of each simulation and multiply it by the simulation weight to receive the amount of energy used by approximately 650 homes of the same parameters as the corresponding simulation home. Energy use for each simulation is then summed and grouped by time and location. The peak demand for each day is found to create a daily peak demand curve for Texas and for its regions over one year. Data from the "base" case are compared to data from the "upgrade" case where gas and propane furnaces are replaced with an electric heat pump.

Weather Files

TMY (typical meteorological year) and AMY (actual meteorological year) weather files from 13 locations within ERCOT are used in the energy model. Documentation from NREL determine how many single-family detached houses correspond with each weather file [18]. This information is shown in Table 2. The energy model selects homes from each weather file region proportionally to how many homes are listed in Table 2.

AMY weather files from 2011 for the 13 locations in ERCOT were acquired to model how energy use would have changed during 2011 had the entire state used heat pumps for heating. The year 2011 was chosen because of its very cold winter and very hot summer statewide, making it is a good candidate year to stress test the system in both the winter and the summer. This weather year is also often used by the Texas grid operator to simulate a high demand year.

Table 2. Number of homes simulated for each weather file region.

Weather File Locations	Homes
Abilene, TX	111,982
Austin, TX	503,831
Brownsville, TX	276,529
Corpus Christi, TX	210,727
Dallas, TX	1,790,296
Houston, TX	1,489,192
Lufkin, TX	185,112
Midland, TX	124,086
San Angelo, TX	57,518
San Antonio, TX	651,578
Victoria, TX	92,002
Waco, TX	227,149
Wichita Falls, TX	177,316
Total Homes	5,897,318

Results and Discussion

Results from each scenario are presented with a daily peak demand scatter plot and a load duration curve. We used multiple heat pump models with different efficiencies to test the implications for electrifying residential heating with systems commonly installed today as well as with a very high efficiency unit, also commercially available today, but less often installed. The lower efficiency unit is a SEER 14, 8.2 HSPF heat pump and is based on a typical model used in NREL's BEopt software. The higher efficiency unit is a SEER 29.3, 14 HSPF heat pump and is based on the Fujitsu AOU*RLS3H series [5]. The higher efficiency model is an unducted mini-split unit. Duct systems are a major source of performance loss for heat pumps. Almost all heat pumps manufactured today that require a duct system struggle to achieve an HSPF greater than 11 [20]. The prospect of the entire residential sector adopting ductless heat pumps might be unlikely, but the high efficiency scenarios are still valuable and represent the technical bounds of the problem. Figures 10 and 11 display a scenario (2011 Blend) where 60% of the residential sector uses the standard efficiency ASHP and 40% use the ductless MSHP system. Similarly, Figures 12 and 13 display the same 60%/40% blend of heat pumps except with TMY weather data.

Figure 2 through Figure 13 show results for every case of our analysis. The red points and lines in the graphs below reflect the base-case (current Texas heating mix) case and the blue points and lines reflect the electrification case. Note that these graphs show single family residential electricity demand for all end uses, not just that for space conditioning.

Figures 2, 4, 6, 8, 10, and 12 show the daily peak demand values for one year for each scenario. The base scenario in each figure (red points) is representative of how the current residential building stock would respond to the modeled weather files. In this scenario, the maximum residential demand occurs in mid to late summer, driven by large air conditioning loads responding to high outdoor temperatures. There is usually a smaller winter peak, occurring in late January or early February. The winter peak is less than the summer peak because the majority of space heating in ERCOT is powered by natural gas rather than electricity. The electrification scenario (blue dots) shows how electrified space heating would alter the base scenario. For example, in Figure 2, the single family residential sector peak moves from the summer to the winter and increases by more than 11 GW.

Figure 3, 5, 7, 9, 11 and 13 show the same data as Figures 2, 4, 6, 8, 10 and 12, respectfully, but in a different way. In particular the daily peak demand values (blue and red dots) are ordered from highest daily demand to lowest to form a type of load duration curve. Load durations curves are helpful for showing the percentage of time that the load is above a certain level. For example, in Figure 3, which shows the same data as in Figure 2, the load duration curve indicates that about 50% of the time, the daily peak demand of the single family residential sector exceeds 10 GW and only about 10% of the time does the load exceed about 22 GW. The very steep section of the load duration curve (on the left side) also indicates how "peaky" the demand is, i.e. the steeper the curve the higher the peak demand is relative to the average or median demand. A steep load duration curve is harder for traditional grids to deal with because it indicates that the system will need a high level of supply for a short amount of time (here a number of days). Figure 3 also allows for comparisons between scenarios and indicates that the electrification scenario, although similar to the base case scenario for most of the time, has a much higher peak demand. Figure pairs 4 & 5, 6 & 7, 8 & 9, 10 & 11, and 12 & 13 are similar to Figure 2 & Figure 3 except that the weather files and heat pump selections are varied.

According to the results below, some general takeaways are that full electrification of the residential sector's space heating fleet will create a winter peaking single-family residential sector. In most cases, a higher level of power plant capacity would be needed to cover the increased demand. However, the total amount of electricity consumed annually either increases or decreases depending on which heat pump is utilized. Each electrification scenario results in less natural gas consumption in the residential sector. Utilizing the air-source heat pump (ASHP) increases electricity consumption, but installing the more efficient mini-split heat pump (MSHP) results in a decrease. The 2011 blend scenario, where 60% of the residential sector uses the standard efficiency ASHP and 40% use the ductless MSHP system, results in overall electricity savings. Table 3 shows the net change in annual electricity and gas consumption between the electrified scenario and the base-case scenario. The table also shows average savings for consumers on both electric and gas bills. Every scenario shows a reduction of house-hold energy costs from reduced natural gas usage. The scenarios with a high efficiency heat pump see larger per year electric bill savings. The emissions implications of the scenarios are shown in Table 5.

Table 3: Net change in annual electricity and gas consumption. Net savings on utility bills were calculated from assuming 0.1093 $/kWh and 0.8407 $/therm of natural gas. As a reminder, we used 2011 weather data to simulate an extreme weather year, not to try to simulate energy use and peak demand in 2011.

	Net Change in Consumption		Savings	
Scenario	Electricity (GWh)	Gas (billion BTU)	Total Savings (thousands $)	Savings per Household ($)
2011 ASHP	+536	-70,715	$536	$90.89
2011 MSHP	-18,935	-70,703	$2,665	$451.90
2011 Blend	-7,252	-70,710	$1,388	$235.36
TMY ASHP	+2,685	-75,568	$341	$57.82
TMY MSHP	-12,467	-75,657	$1,999	$338.97
TMY Blend	-3,376	-75,604	$1,004	$170.28

2011 Weather Data: ASHP – 14 SEER 8.2 HSPF

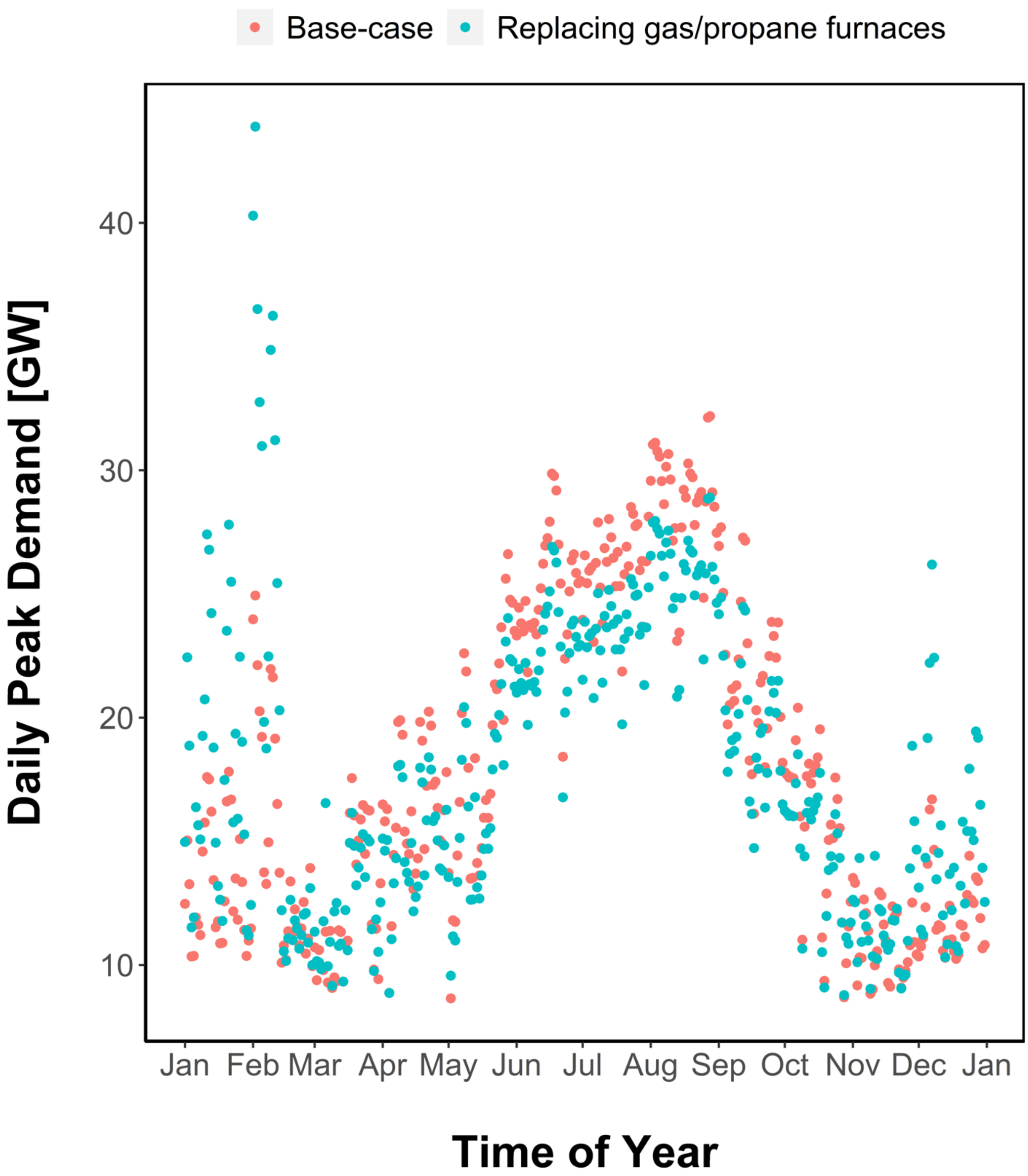

Figure 2. Daily peak demand for 2011 weather data and standard efficiency heat pump. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

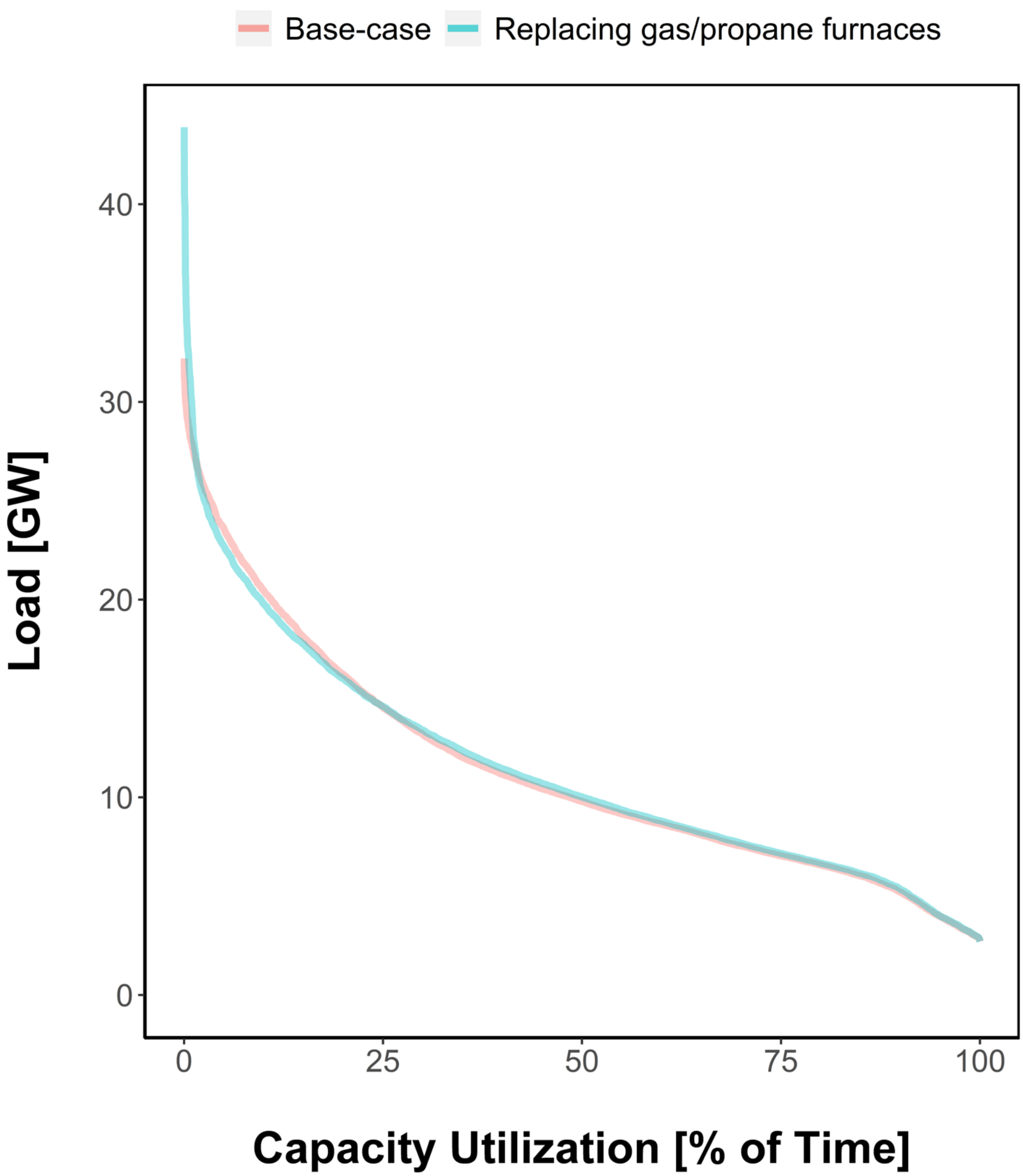

Figure 3. Load duration curve for 2011 weather data and standard efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

TMY Weather Data: ASHP – 14 SEER 8.2 HSPF

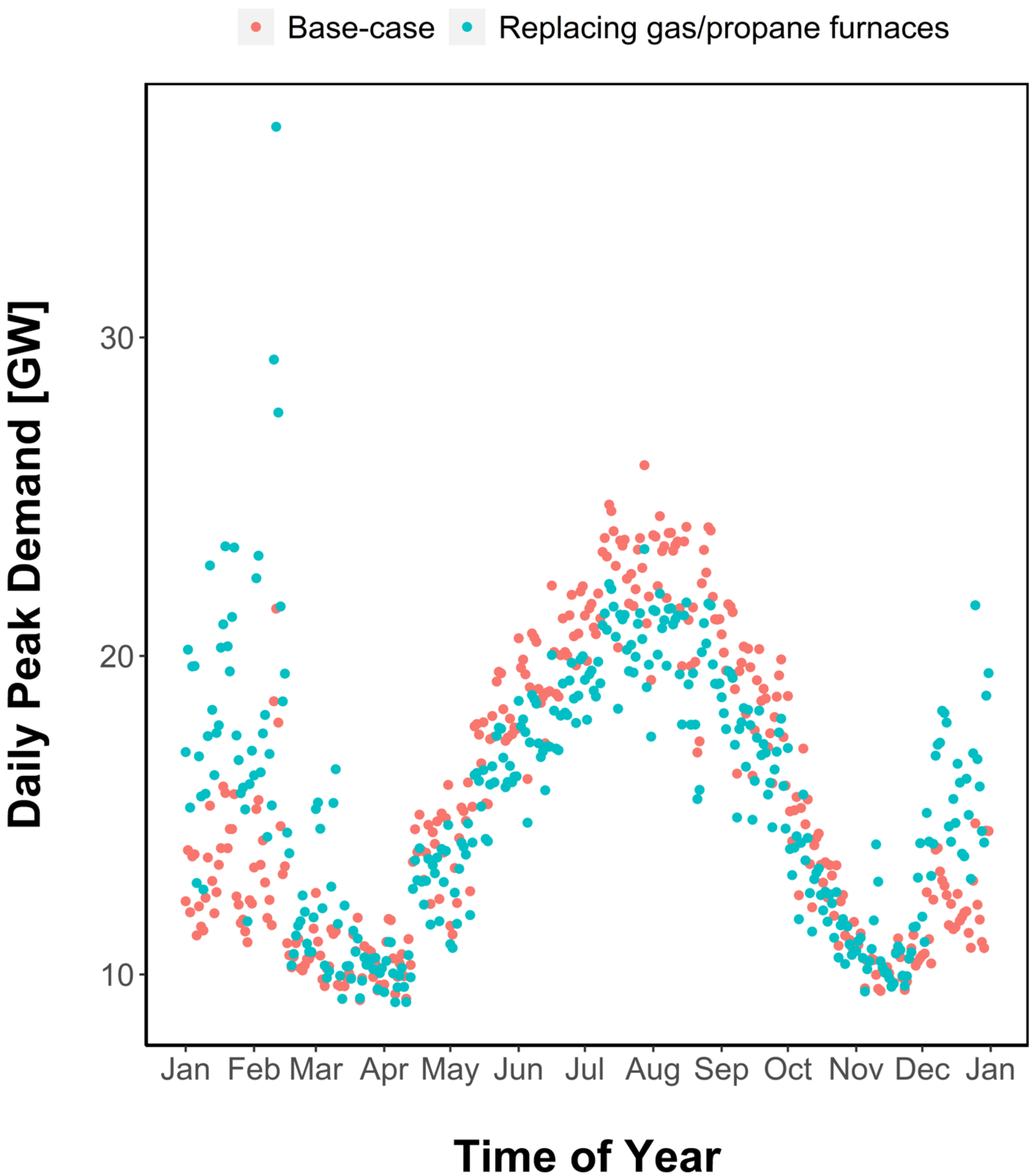

Figure 4. Daily peak demand for TMY weather data and standard efficiency heat pump. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

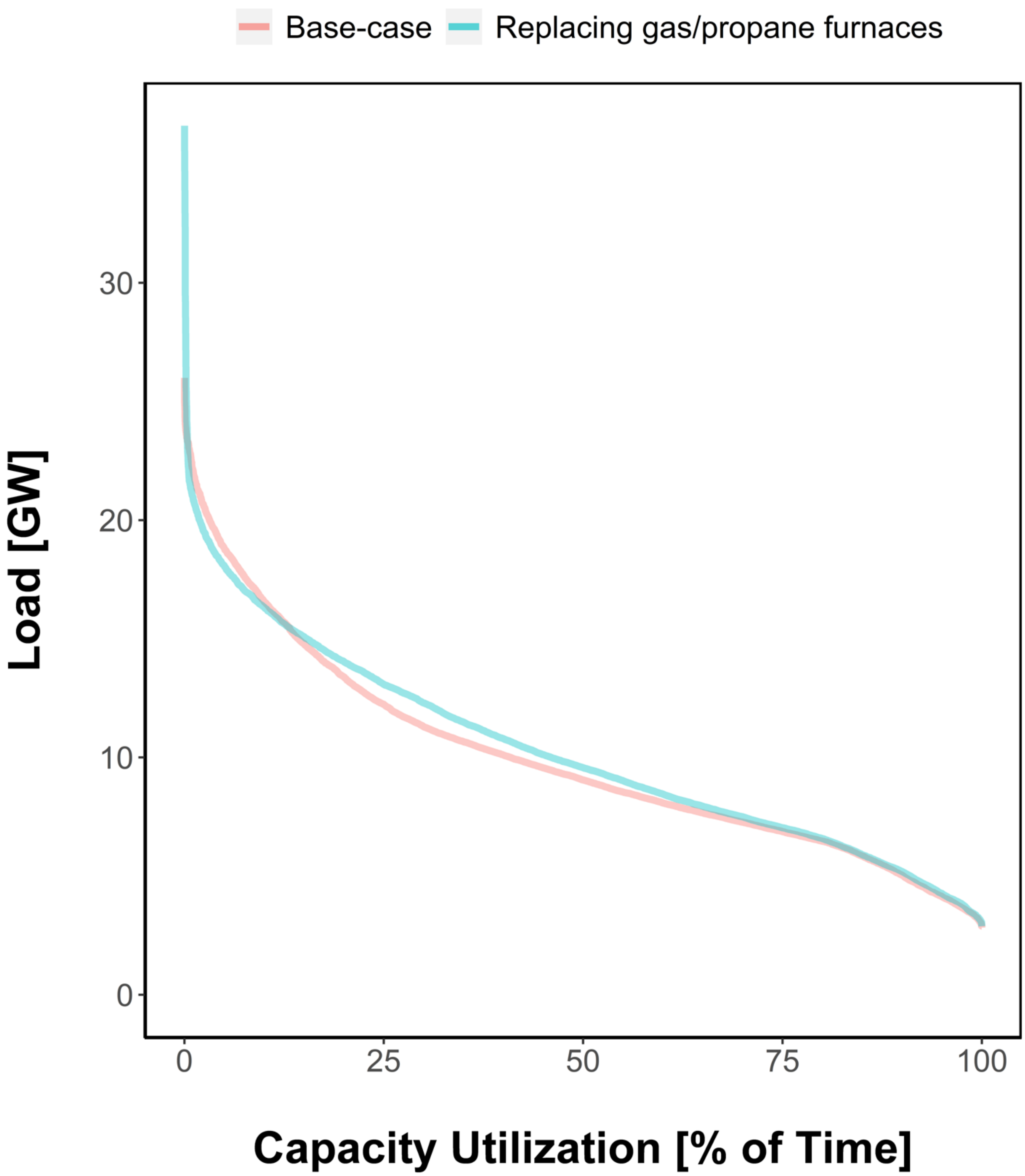

Figure 5. Load duration curve for TMY weather data and standard efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

2011 Weather Data: MSHP – 29.3 SEER 14 HSPF

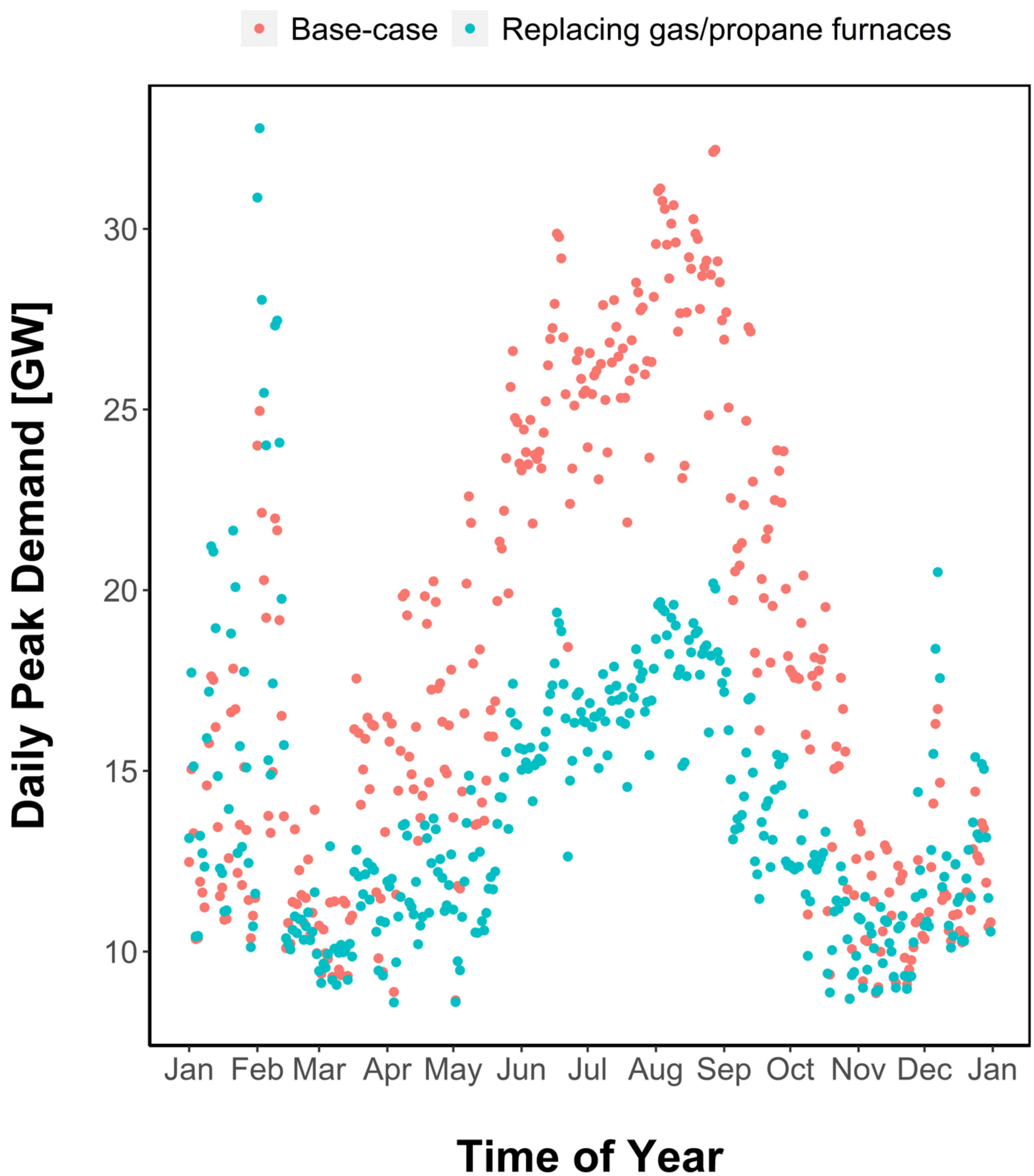

Figure 6. Daily peak demand for 2011 weather data and high efficiency heat pump. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

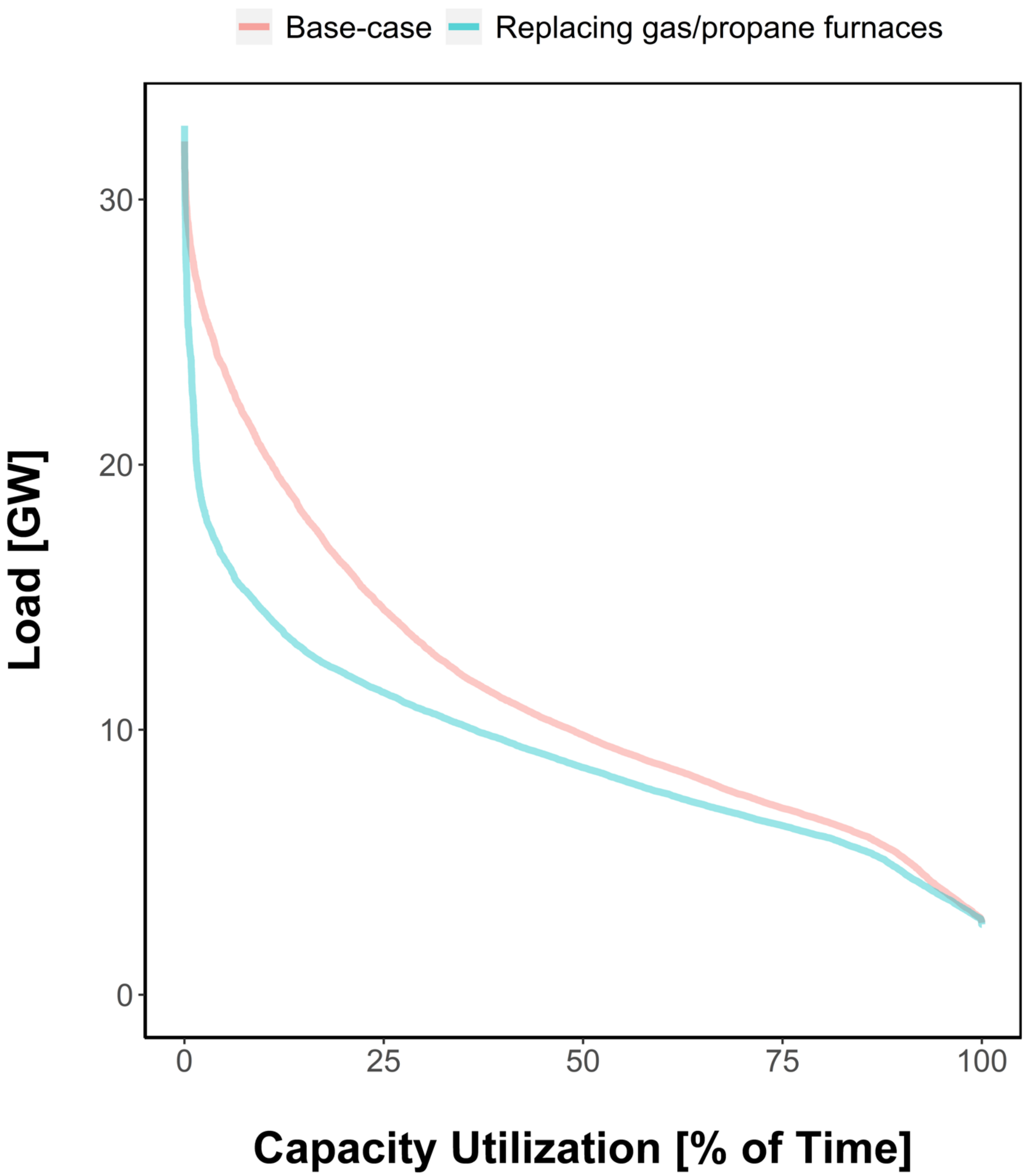

Figure 7. Load duration curve for 2011 weather data and high efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

TMY Weather Data: MSHP – 29.3 SEER 14 HSPF

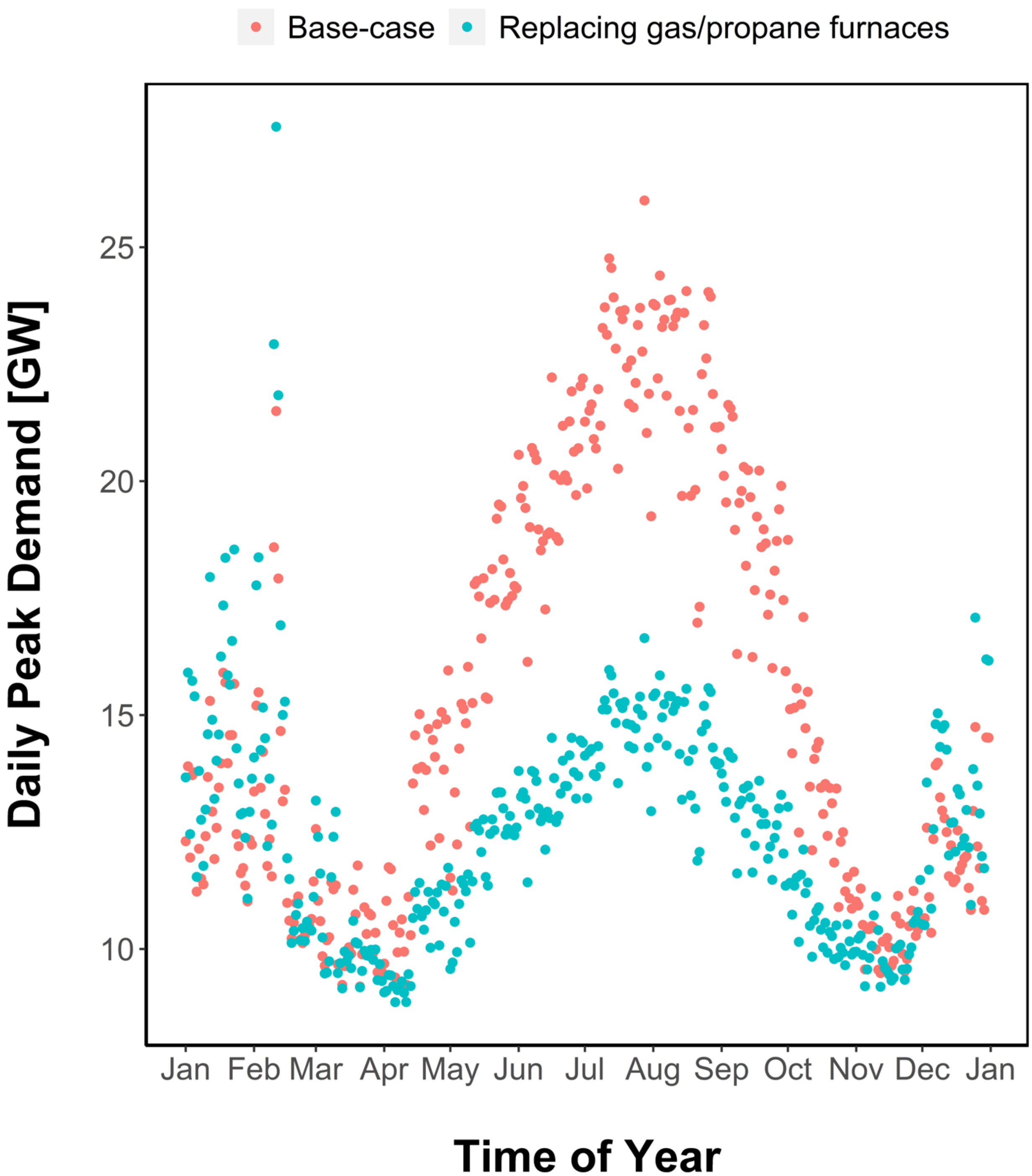

Figure 8. Daily peak demand for TMY weather data and high efficiency heat pump. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

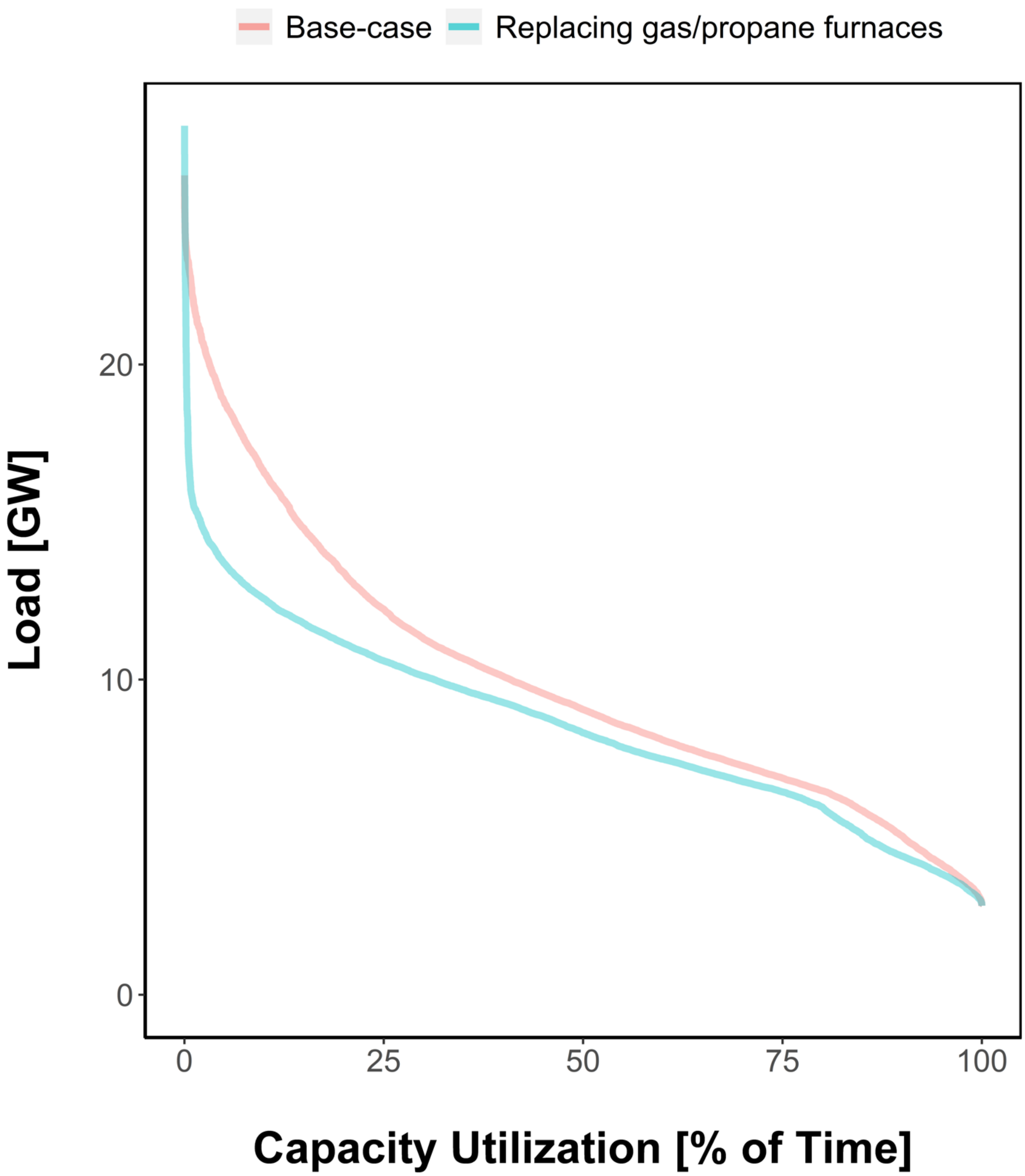

Figure 9. Load duration curve for TMY weather data and high efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

2011 Weather Data: 40% MSHP – 29.3 SEER 14 HSPF and 60% ASHP – 14 SEER 8.2 HSPF

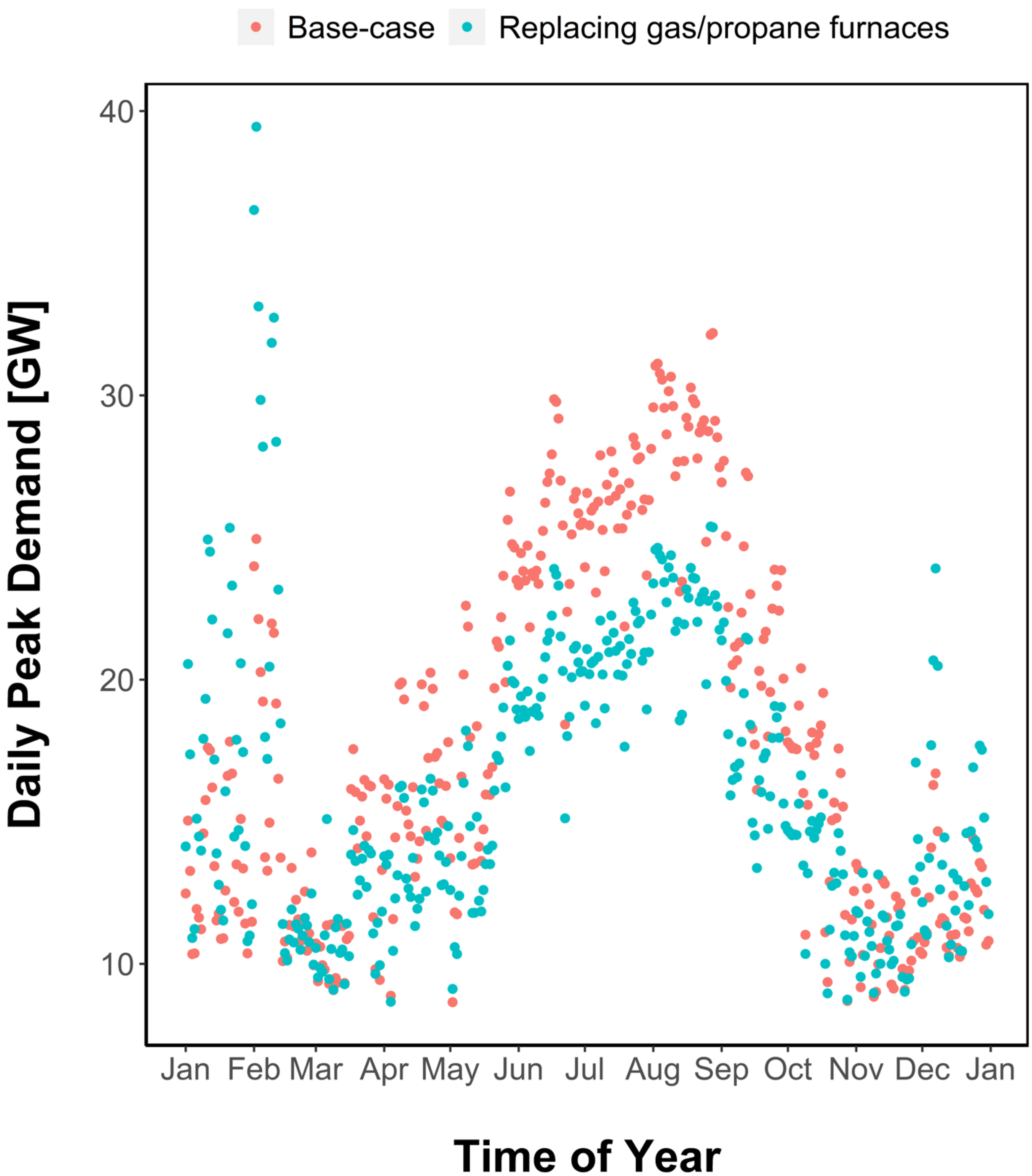

Figure 10. Daily peak demand for 2011 weather data and scenario where 40% of residential sector uses high efficiency heat pumps and 60% of sector uses standard efficiency heat pumps. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

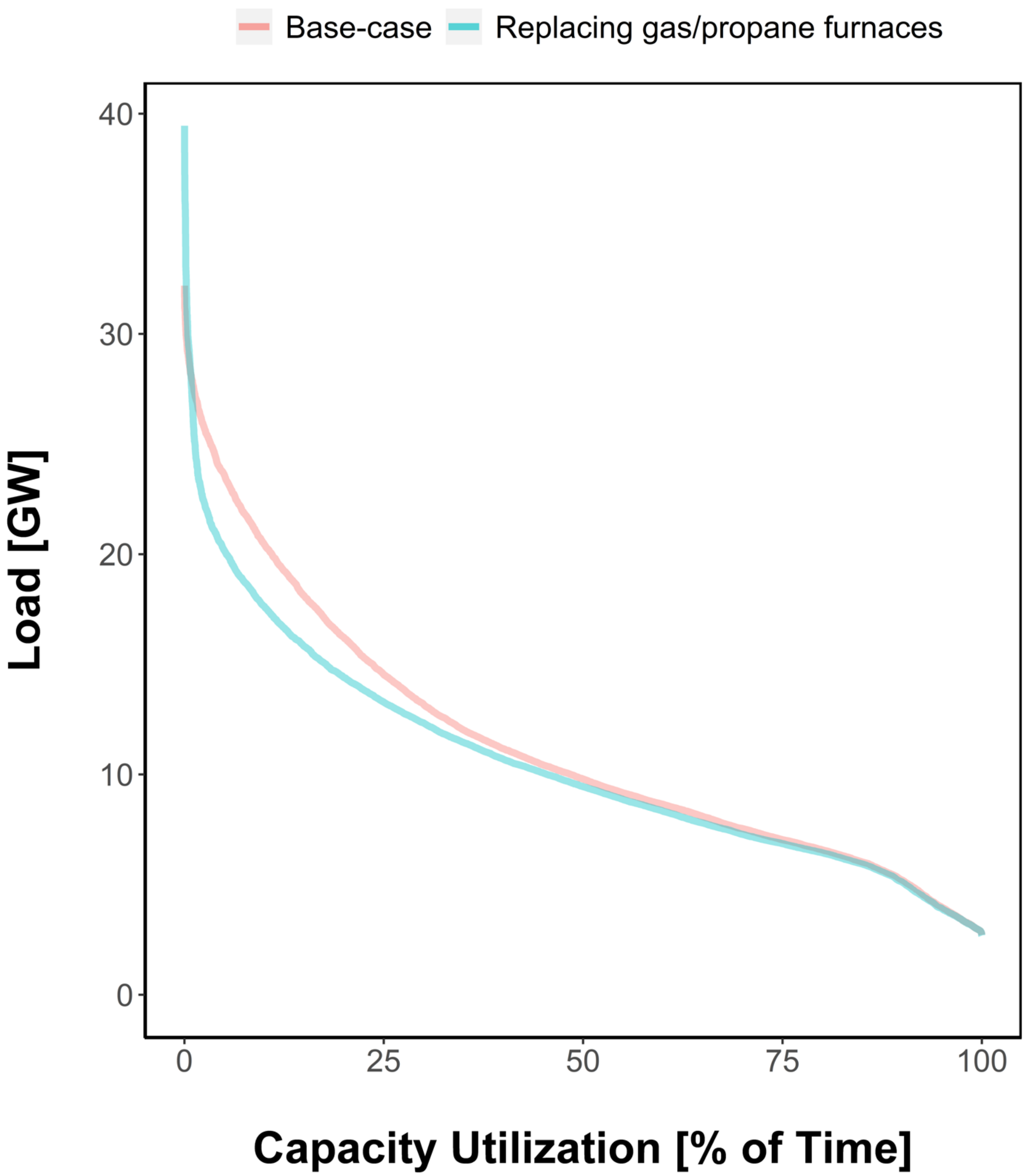

Figure 11. Load duration curve for 2011 weather data and scenario where 40% of residential sector uses high efficiency heat pump and 60% of sector uses standard efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

TMY Weather Data: 40% MSHP – 29.3 SEER 14 HSPF and 60% ASHP – 14 SEER 8.2 HSPF

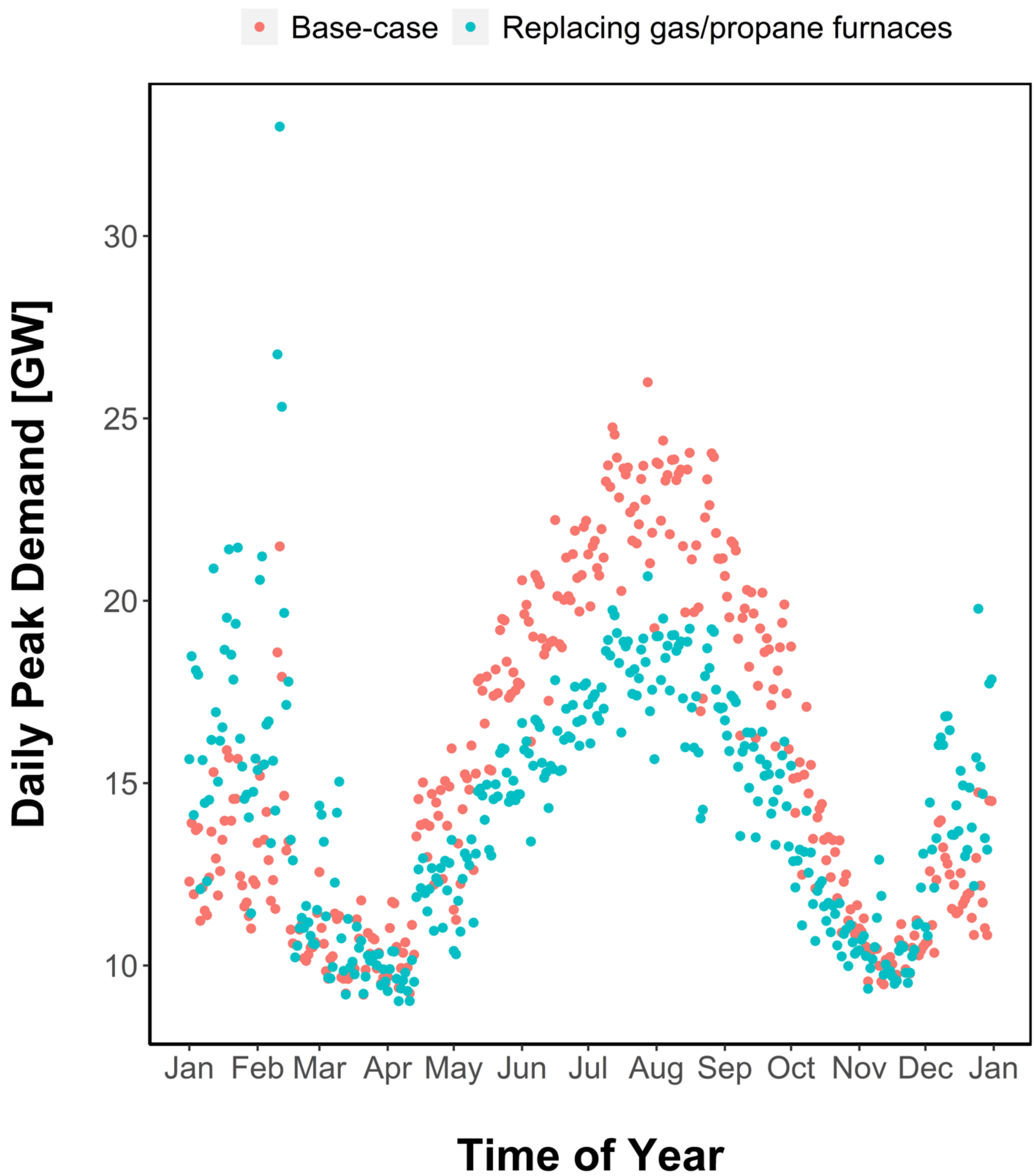

Figure 12. Daily peak demand for TMY weather data and scenario where 40% of residential sector uses high efficiency heat pumps and 60% of sector uses standard efficiency heat pumps. Red dots are the base case and blue dots are the electrification case. These values are for the single-family residential sector only, not the entire grid.

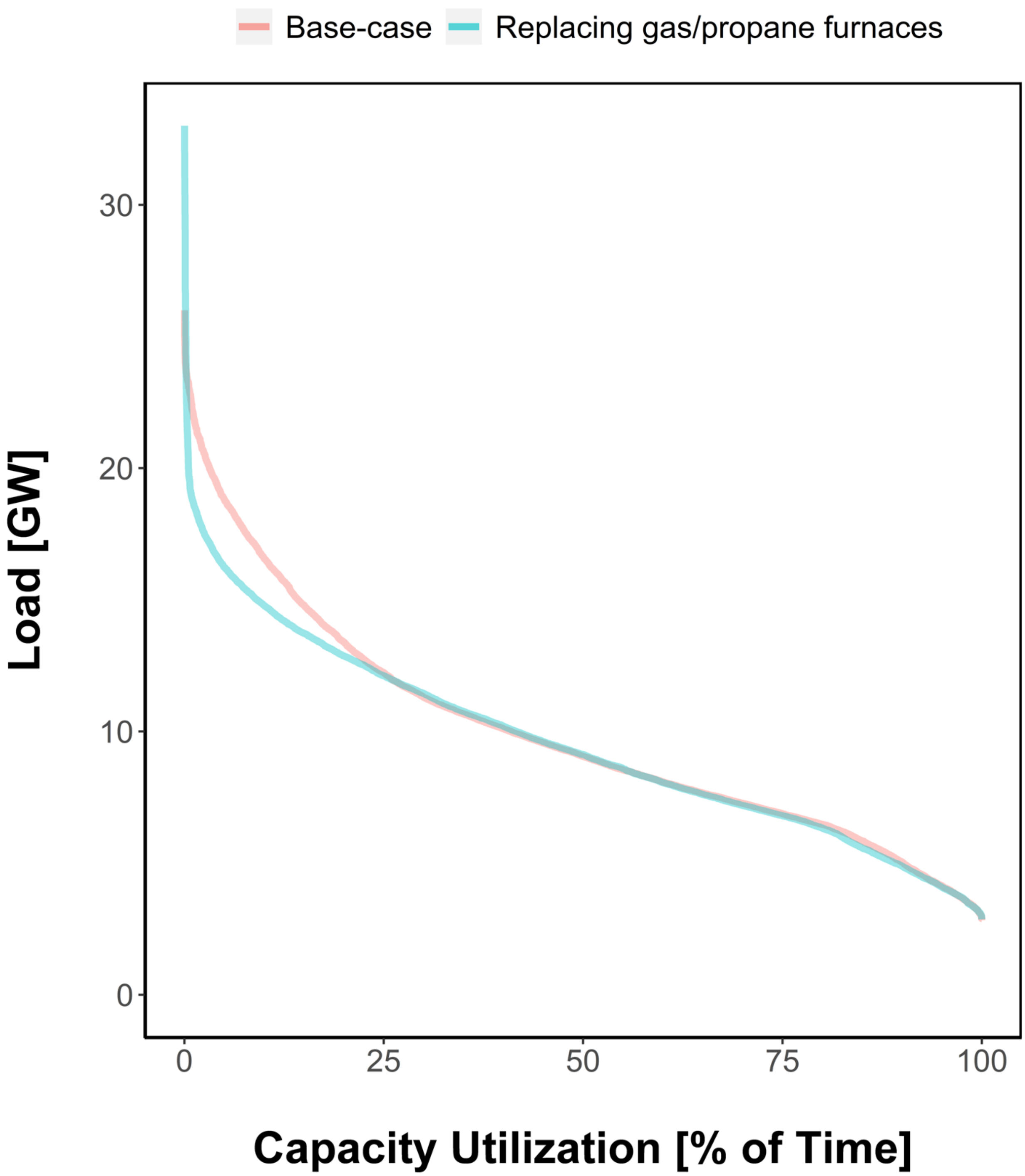

Figure 13. Load duration curve for TMY weather data and scenario where 40% of residential sector uses high efficiency heat pump and 60% of sector uses standard efficiency heat pump. The red line is the base case and the blue line is the electrification case. These values are for the single-family residential sector only, not the entire grid.

Table 4. Net change and percent difference between peak demand of the base-case and each scenario.

Scenario	Base Summer Peak (GW)	New Summer Peak (GW)	Base Winter Peak (GW)	New Winter Peak (GW)
2011 ASHP	32.2	28.9	24.9	43.9
2011 MSHP	32.2	20.2	24.9	32.8
2011 Blended	32.2	25.38	24.9	39.4
TMY ASHP	26	23.4	21.5	36.6
TMY MSHP	26	16.6	21.5	27.6
TMY Blended	26	20.7	21.5	33.0

Peak Demand Implications

Each electrification case shows the aggregated maximum daily peak demand for single-family detached homes in ERCOT shifting from the summer to the winter. In all scenarios, the results show a winter peak higher than the base-case's summer peak. For the standard-efficiency heat pump, the winter peak is about 10.6 to 11.7 GW higher than the base-case summer peak, depending on the weather chosen. For the high-efficiency heat pump, the winter peak is around 0.6 to 1.6 GW higher than the base-case summer peak, depending on the weather chosen. The blended (60% standard-efficiency 40% high-efficiency heat pump) scenario shows a winter peak between 7.0 and 7.2 GW higher than the base-case summer peak, depending on the weather chosen. Again, these reported values are for the single family detached residential sector only and thus should be considered in the context of the entire ERCOT grid. The residential sector is only part of the total ERCOT demand and, in general, winter demands are lower than summer demands in other sectors of the economy (commercial and industrial), so these data should be considered in that context.

Emissions Implications

Table 5 shows the emissions change from the base case to replacing all gas and propane furnaces with an electric heat pump. These numbers also include offsetting emissions from natural gas furnaces. Furnace emissions assume 100% efficiency of combustion and are derived from EPA data [9]. The electricity emissions intensity is based on the average per MWh emission data for Texas in 2017 [21]. However, the emissions intensity of the electricity grid in Texas has been falling. ERCOT reported that wind and solar made up about 20% of all electricity consumption in 2018 and both are expected to continue to grow. Thus, these numbers likely indicate a conservative estimate of the emissions savings because as the emissions of the electricity grid fall, so do the emissions associated with electrified heating. While times of grid peak demand can have high emissions intensities because of the use of inefficient peaking power plants, new winter peak demands are also more aligned with times of strong wind output. Also, very high-efficiency heat pumps generally use much less electricity in the summer and, in Texas, use less energy overall. As coal plants in Texas continue to shut down, the sulfur dioxide emissions will lower because coal plants emit the vast majority of sulfur pollutants.

Table 5. Emission change on electrical grid from base case to replacing gas and propane furnaces with an electric heat pump for the state of Texas.

Scenario	Carbon Dioxide (thousand metric tons)	Sulfur Dioxide (metric tons)	Nitrogen Oxide (metric tons)
2011 ASHP	-3,469	316	-2,756
2011 MSHP	-13,767	-11,165	-9,821
2011 Blended	-7,588	-4,276	-5,582
TMY ASHP	-2,590	1,583	-2,179
TMY MSHP	-10,609	-7,351	-7,681
TMY Blended	-5,798	-1,990	-4,380

Cash Flow Implications

We also developed a cash flow scenario for a generic 1,600 square foot home located in Central Texas with 1 floor, 3 bedrooms, and two bathrooms.

Table *6* shows the different scenarios used to replace the base case as well as financial inputs used to calculate costs. Each scenario's heat pump is sized at 48 kBtu/h (4 tons). Figure 14 shows the annualized utility bill in dollars per year. The high efficiency MSHP yields the least expensive yearly energy bills to the homeowner (assuming energy costs of $0.1093/kWh and $0.8407/therm of gas).

Figure 15 shows the annualized energy costs for each heat pump considered against the its source energy savings. The annualized energy related costs factors in capital costs for purchasing the heat pumps, whereas the utility bill calculations do not. Because of higher upfront purchase costs, the high efficiency MSHP yields the highest annualized energy costs, even higher than the base case. The source savings reflect the amount of electricity saved for using a more efficient unit in the home. Figure 15 indicates that the 22 SEER 10 HSPF variable speed heat pump is the optimal selection when balancing energy related costs and energy savings. However, as the cost of energy increases, the more efficient unit could start to look more economically attractive.

Table 6. Cash flow analysis information.

Cash Flow Scenarios	
Base Case	SEER 13 AC / Natural Gas Furnace 78% AFUE
1 Stage Compressor	SEER 13, 7.7 HSPF ASHP
2 Stage Compressor	SEER 16, 8.6 HSPF ASHP
Var. Speed	SEER 22, 10 HSPF ASHP
High eff. Heat Pump	SEER 29.3, 14 HSPF MSHP unducted

Financial/Cost Information	
Price of electricity	0.1093 $/kWh (TX average)
Price of natural gas	0.8407 $/ therm (TX average)
Mortgage Rate	4%
Tax Rate	28%
Time horizon	30 years
Inflation rate	2.40%
Discount rate (real)	3.00%

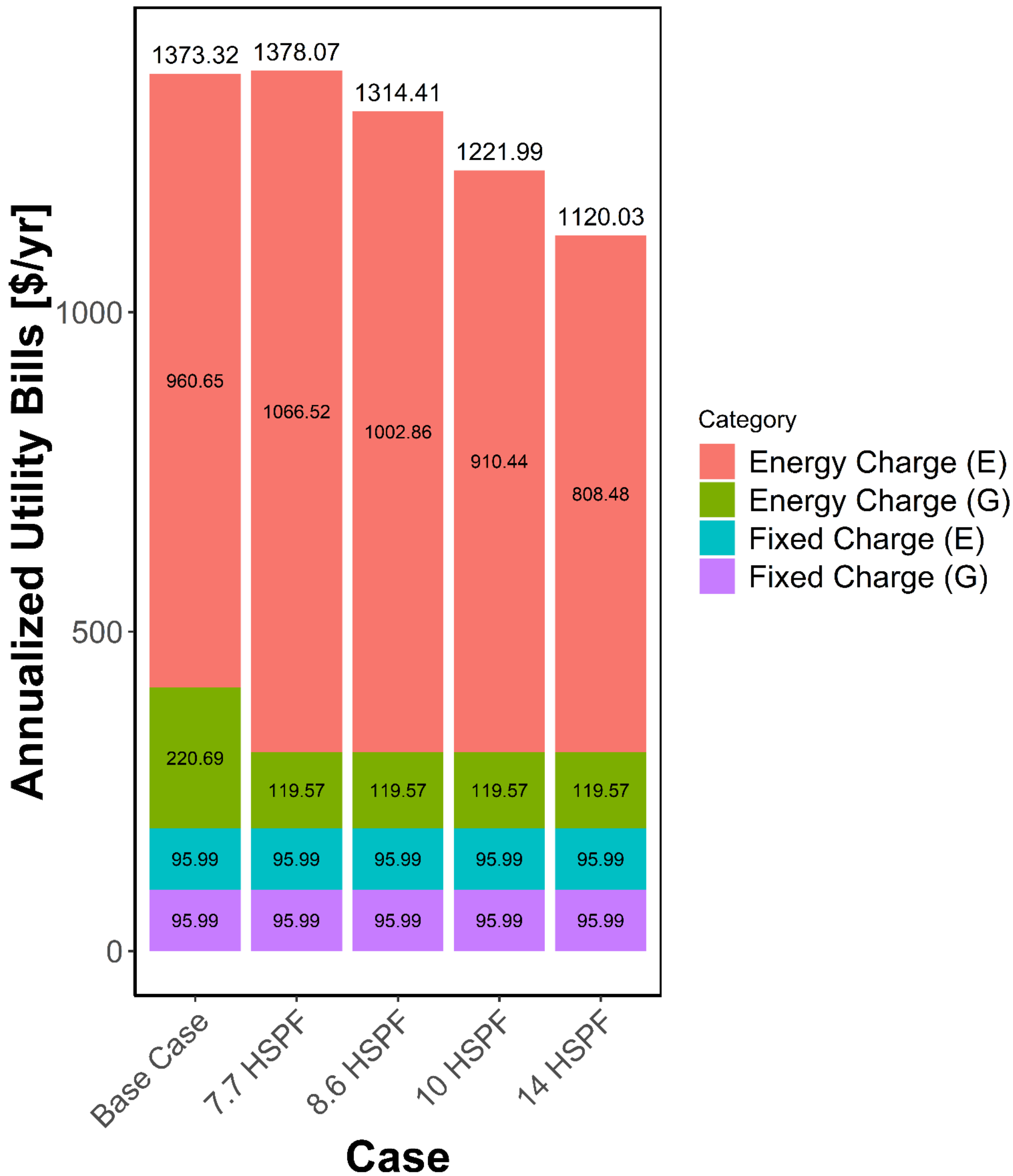

Figure 14. Annualized utility bill cost per year for each scenario considered in the Central Texas cash flow analysis.

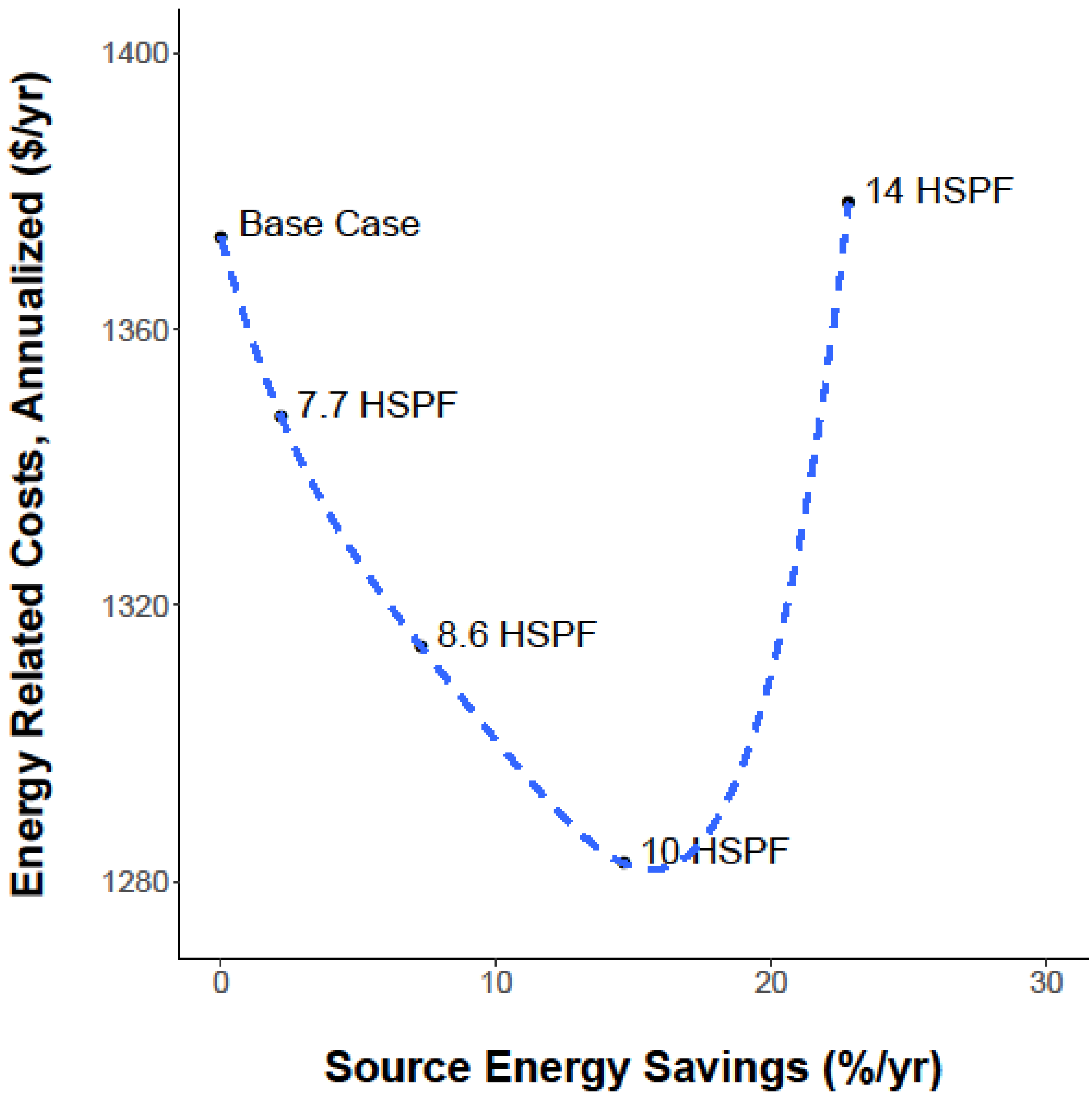

Figure 15. Annualized energy costs for each scenario plotted against source energy savings. The costs takes capital and operating costs into account for each heat pump. The source energy savings reflects how much electricity is saved by having a more efficient (i.e. less consuming) heat pump in the home.

Total grid peak demand estimation

In this section we attempt to extrapolate our results for the single family detached residential sector to the entire grid peak. Figure 16 shows the total, and breakdown by customer class, of the 2016 summer and 2018 winter peak demands in the ERCOT grid (see Appendix). In both cases, the residential sector (including multifamily) constitutes roughly half of the load. The summer of 2016 was an average, or typical summer in Texas, thus we will compare our simulation results using the TMY data, which are designed to represent a typical year [22].

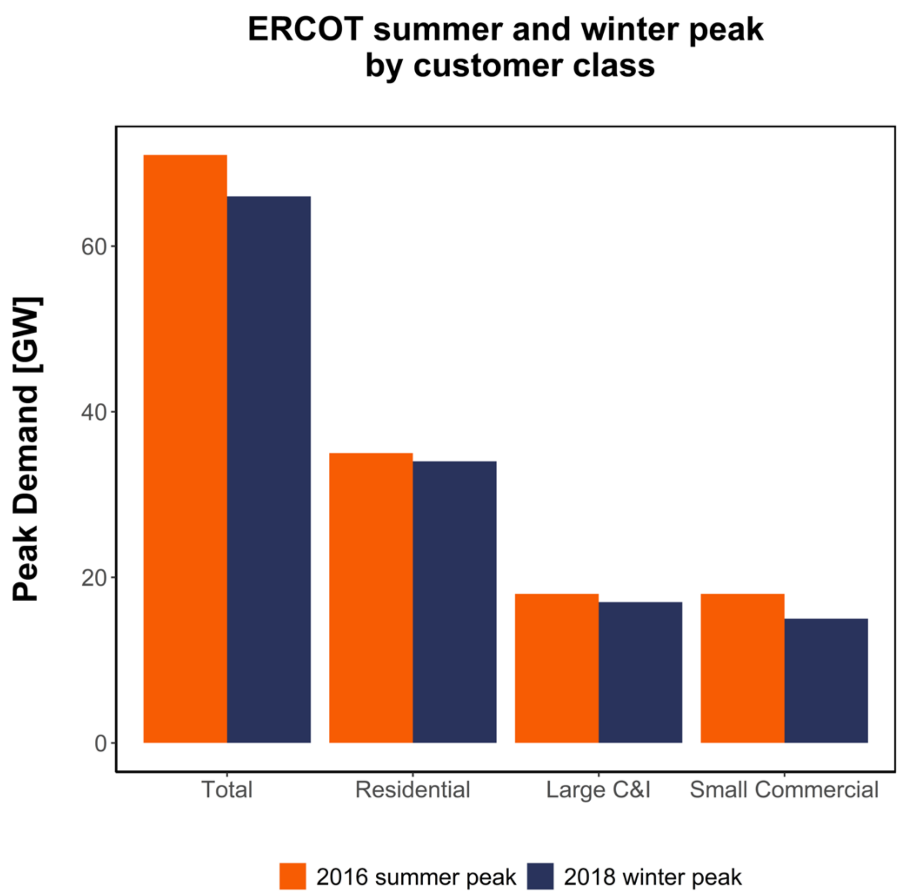

Figure 16: Figure showing the 2016 summer and 2018 winter peak demand in ERCOT broken down by customer class. Data: ERCOT. Large C&I: large commercial and industrial.

The 2016 summer peak demand in ERCOT was just over 71 GW, of which about 34.5 GW was due to the entire residential sector. This analysis simulated only the single family detached residential sector, which constitutes about 80% of the whole residential sector. Taking this percentage as a rule of thumb would indicate that the single family detached sector contributed about 27.6 GW to the overall 2016 summer peak demand. This estimate is consistent with our simulated base-case results of a 26 GW single-family detached summer peak contribution.

Similarly, the 2018 winter peak demand in ERCOT was almost 66 GW, of which about 33.6 GW was due to the entire residential sector. Again using the 80% rule of thumb, this would indicate that the single family residential sector was responsible for about 27 GW worth of winter peak demand, which is similar to the simulated 25 GW single-family detached winter peak contribution using the 2011 data[2].

ERCOT estimates that there is currently about 37 GW of weather-driven summer peak demand (53% of the total) and about 29 GW of weather-driven winter peak demand (44% of the total) in the system, see Appendix. Using the TMY blended (60% ASHP/40% MSHP) scenario from our analysis, we estimate that the summer peak would decrease by about 23% while the winter peak would increase by about 42% for the single-family detached residential sector. If we then assume that this winter increase and summer decrease in peak demand would hold across all sectors and apply those changes to the total amount of weather-driven peak-demand during the summer and winter peaks, we can estimate how the total ERCOT peak demand might change.

Thus, we estimate that, under the 60/40 blend scenario, the summer 2016 peak demand in ERCOT would have been around 62.5 GW (~8.5 GW reduction) and the 2018 ERCOT winter peak would have been about 78.1 GW (~12.3 GW increase).

If we use those summer and winter peaks as a starting point and project them forward by 20 years assuming that each grow by about 2% per year (the former is roughly in line with ERCOT's projections found in its 2018 long-term system assessment report [23]) we can estimate how ERCOT's future peak demand might change under our electrification scenarios.

[2] 2018 had a cold snap similar to the one experienced in 2011.

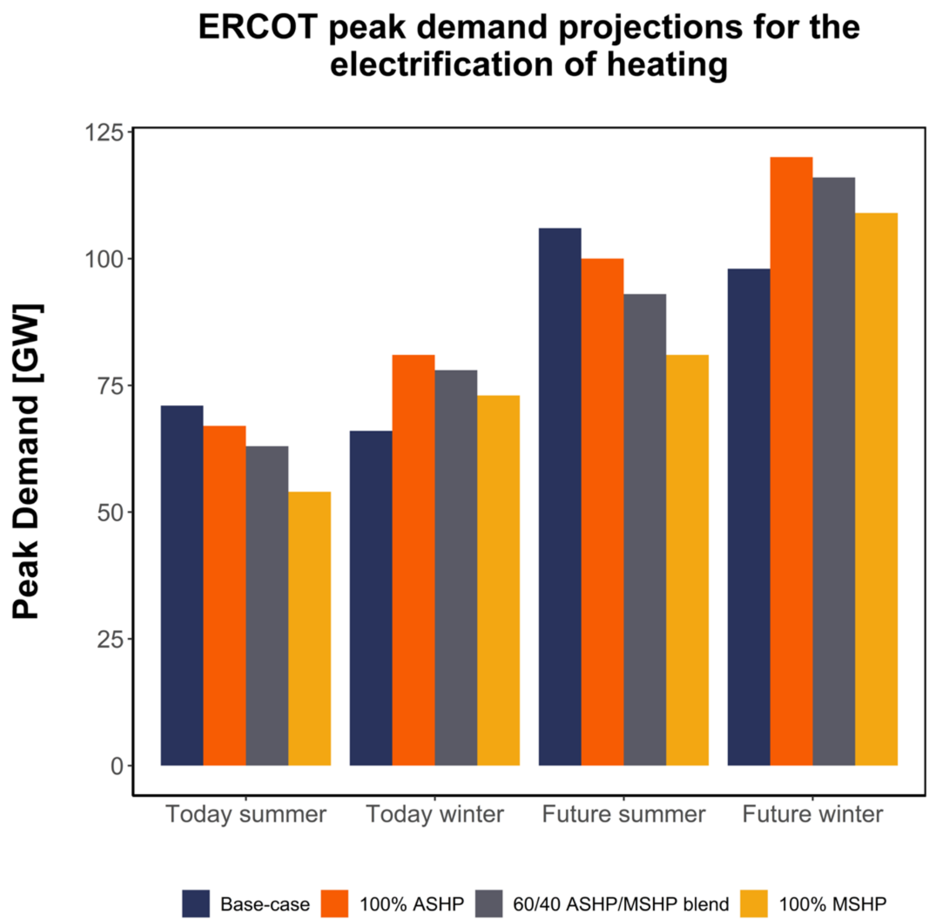

Figure 17: Figure showing the estimated total ERCOT peak demand changes from the electrification of heating. The Today summer and Today winter refer to what we estimate the summer of 2016 peak demand and the winter of 2018 peak demand would have looked like if they had fully electrified heat. The Future summer and Future winter refer to our estimates of what the summer and winter peaks might look like in 20 years considering an annual 2% summer and winter peak demand growth and our electrification scenarios.

Figure 17 indicates that switching to heat pumps could reduce summer peak significantly, due to the higher efficiencies of the current residential air-conditioning stock. However, all cases of electrifying residential heat result in higher winter peaks, and totally electrifying all heating could result in a winter peaking grid.

While this analysis only modeled the Texas grid, its results could be generalized across the southern US. Electrifying heating in more heating-dominated northern locations would almost certainly cause steeper growths in winter peak demands.

Conclusion

This analysis considered the impacts of switching single-family detached homes in Texas to electric heating. We considered both a mid- and high-efficiency heat pump unit and simulated the widespread adoption of those units using typical weather data as well as data from 2011, which included both a very cold winter and very hot summer. We utilized NREL's ResStock analysis Tool which allowed us to simulate the entire single family residential sector (80% of all residential buildings). We found that in every electrification case that the single-family detached residential sector switched from having its peak in the summer to the winter. The mid-level efficiency heat pump resulted in the single family residential sector consuming 2.6 TWh more electricity, but consuming 76 trillion BTU less of natural gas using TMY weather. The high efficiency heat pump resulted in an overall reduction in both electricity (12.5 TWh) and gas (76 trillion BTU) using TMY weather. In all cases, electrification reduced the amount of carbon dioxide and nitrogen oxide emissions, but the mid-level efficiency ASHP resulted in increased sulfur dioxide emissions due to more grid electricity being consumed. However, as the ERCOT grid becomes cleaner, emissions associated with electrified heat would continue to decline.

We also ran multiple cash flow analysis for a home in Central Texas to determine what would be the optimal heat pump based on both energy bills and installation costs. We found that a heat pump between the mid and high efficiency unit considered in the main analysis would deliver the most economic benefit.

We also extrapolated our analysis to the entire grid and estimate that electrification of space conditioning would likely result in lower summer peaks because the units installed would be more efficient than the current air-conditioning stock. We also estimate that electrification of space conditioning would result in higher overall winter peaks, exceeding both current and future summer peaks.

Acknowledgements

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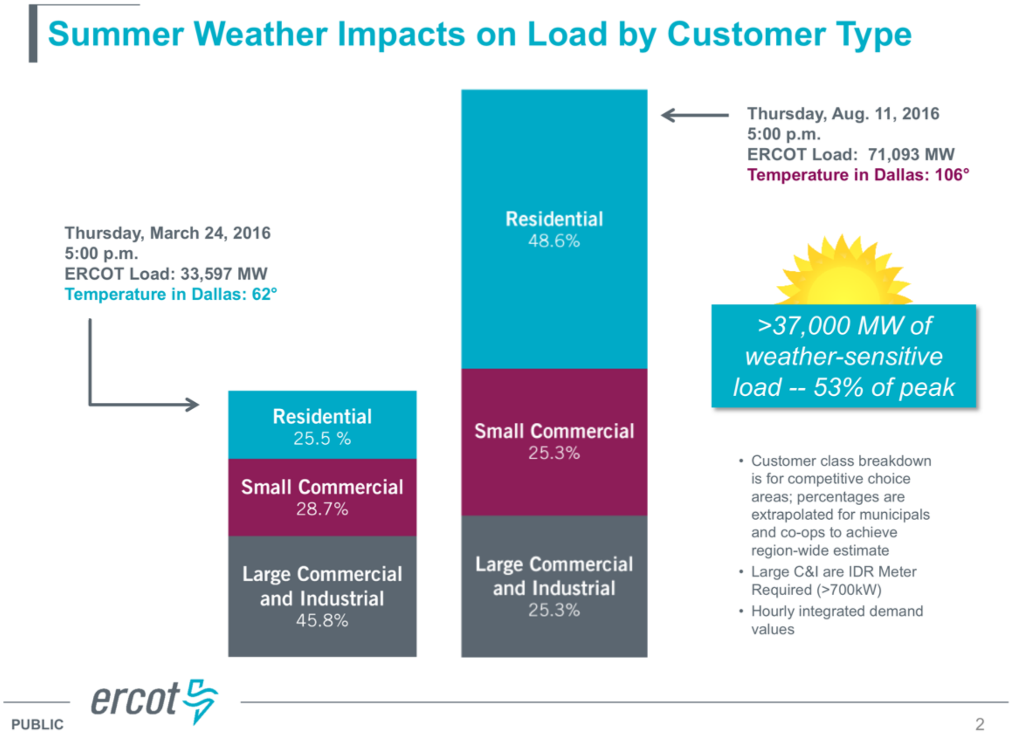
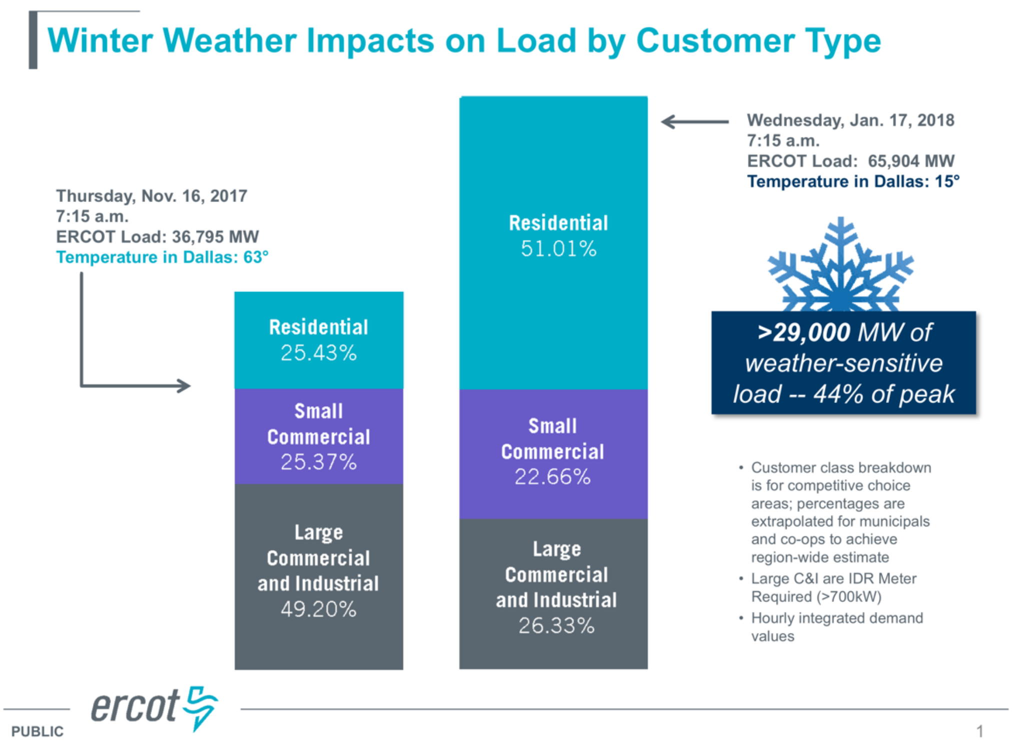
Appendix

Housing parameters considered in ResStock simulations:

Bathroom Spot Vent Hour	Insulation Pier Beam
Ceiling Fan	Insulation Slab
Clothes Dryer	Insulation Unfinished Attic
Clothes Washer	Insulation Wall
Cooking Range	Lighting
Cooling Setpoint	Location Region
Days Shifted	Location
Dehumidifier	Mechanical Ventilation
Dishwasher	Misc Extra Refrigerator
Door Area	Misc Freezer
Doors	Misc Gas Fireplace
Ducts	Misc Gas Lighting
Eaves	Misc Gas Grill
Geometry Foundation Type	Misc Hot Tub Spa
Geometry Garage	Misc Pool
Geometry House Size	Misc Well Pump
Geometry Stories	Natural Ventilation
Heating Fuel	Neighbors
Heating Setpoint	Occupants
Hot Water Distribution	Orientation
Hot Water Fixtures	Overhangs
HVAC System Combined	Plug Loads
HVAC System Cooling	PV
HVAC System Heating Electricity	Range Spot Vent Hour
HVAC System Heating Fuel Oil	Refrigerator
HVAC System Heating Natural Gas	Roof Material
HVAC System Heating None	Solar Hot Water
HVAC System Heating Other Fuel	Usage Level
HVAC System Heating Propane	Vintage
Infiltration	Water Heater
Insulation Crawlspace	Window Area
Insulation Finished Basement	Windows
Insulation Interzonal Floor	

ERCOT peak demand by customer class





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