Platte River Power Authority Beneficial Buildings Electrification Forecast FINAL

Submitted by Apex Analytics, LLC
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1. Executive Summary

Decarbonization Context

Cities and states across North America, including Fort Collins, Longmont, and the state of Colorado, have set out ambitious decarbonization goals, which include these three major elements with large impacts on the electricity grid:

1. **Decarbonize the electric grid** – increase the share of carbon-free generation.[1]
2. **Electrify transportation** – run cars, trucks, and buses on decarbonized electricity.[2]
3. **Electrify buildings** – switch gas heating, hot water, cooking, and other end uses to using decarbonized electricity.[3]

Study Objectives

The goal of this study was to provide Platte River decision makers with data- driven insights to understand the range of impacts of future beneficial building electrification:

Electricity Consumption Increase	Natural Gas Consumption Decrease	Winter Peak Demand	Summer Peak Demand	Monthly Energy and Demand	Hourly Load Impact Shapes

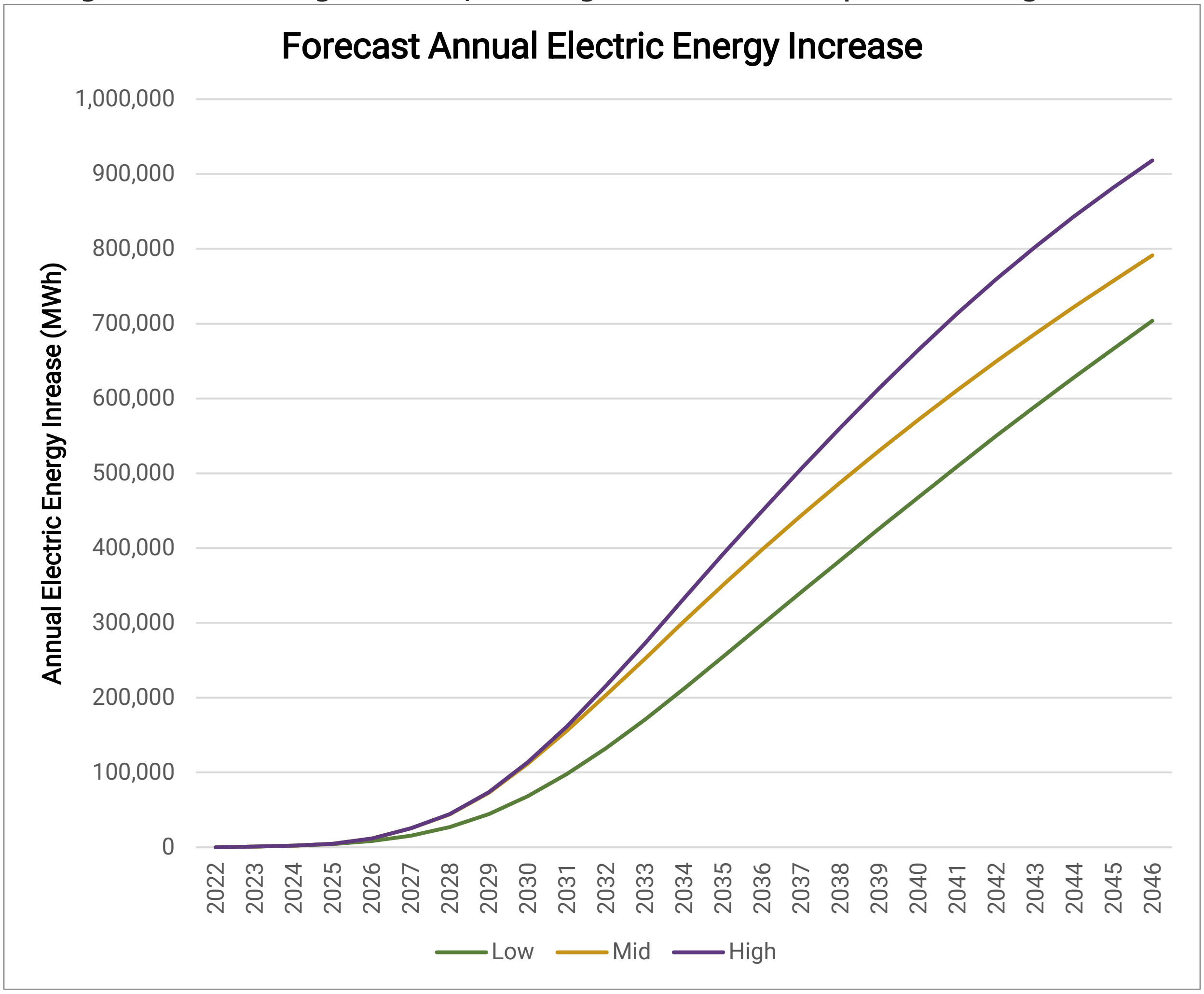
[1] PRPA's latest IRP includes substantial decarbonization of the electricity system by 2031.

[2] Transportation electrification is being forecast under a separate study.

[3] The member cities of Longmont and Fort Collins have started studying building electrification system/customer/ participant impacts along with program design considerations. Report to be made public in spring 2022.

Study Findings

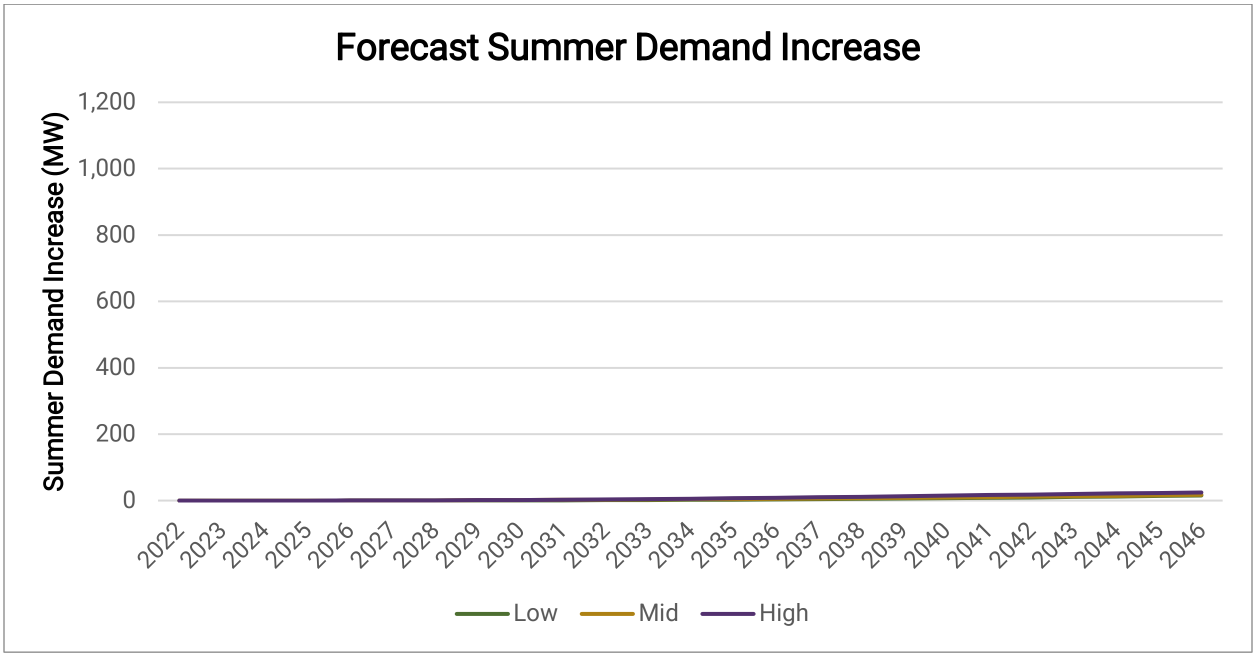
Key Finding 1: Only minor impacts on overall electricity consumption are expected through 2030. Starting in 2030s, building electrification impacts are large.



In each of the plots, Low, Mid, High refer to three modeled adoption scenarios:

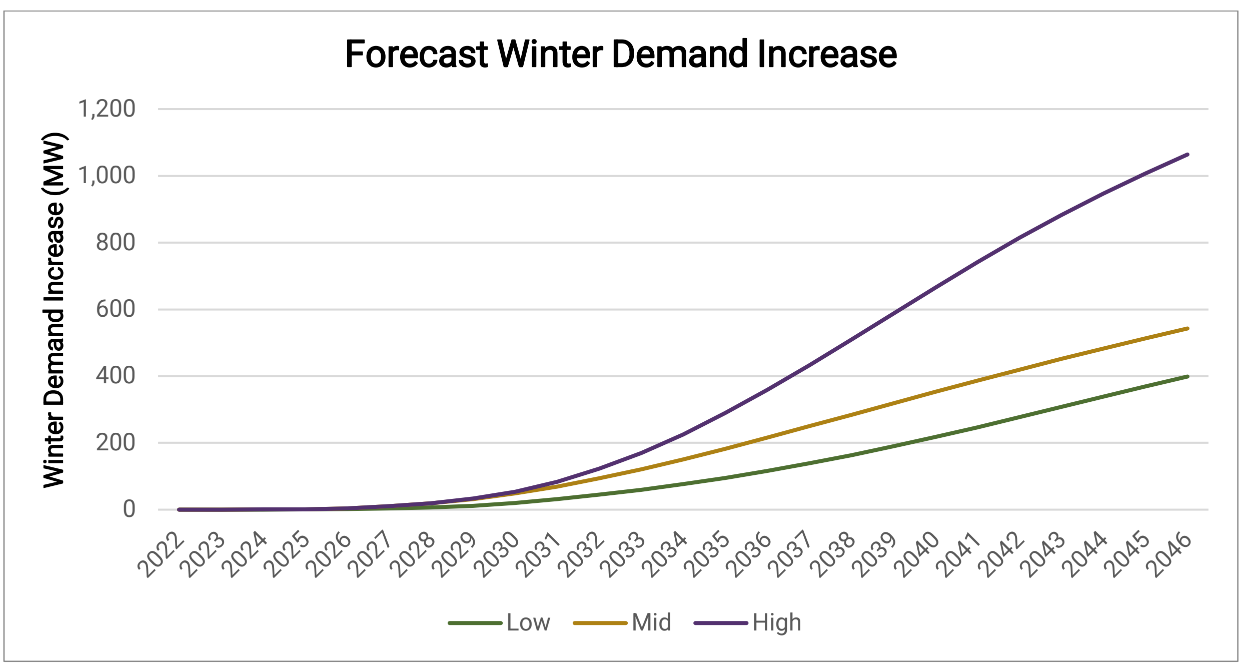
- Low: Assumes significant rebate program and promotion
- Medium: Adds code requirements for all new central air conditioners be heat pumps in 2025 in new construction and 2028 in existing buildings.
- High: Adds requirement for all new construction being all electric after 2030.

Key Finding 2: Summer peak demand impacts are minimal. Load factor improves until switch to winter peaking occurs.



Key Finding 3: Full electrification of heating during extreme cold will cause Platte River to become winter peaking sometime after 2035.

Key Finding 4: Policies requiring all-electric new homes and/or businesses could push impacts sooner – winter peaking will occur within ~5-10 years of requiring all-electric new homes.



Key Finding 5: Electrifying residential space heating with heat pumps is the highest impact building electrification technology.

Sector	End Use	2040 Annual Electricity Impact (MWh)	Percent of Total
Residential	Space Heating	296,480	63%
	Water Heating	17,300	4%
	Cooking	2,063	0%
	Whole Building	45,886	11%
Commercial	Space Heating	94,508	20%
	Cooking	6,558	1%
	Water Heating	4,926	1%

While the building electrification forecast scenarios all show substantial grid impacts, there is also the possibility that program efforts to stimulate market adoption included in the low case do not occur or do not succeed.

Key Finding 6: Partial electrification of heating improved load factor.

Key Finding 7: Full electrification of heating causes significant cost and reliability impacts.

Key Finding 8: Without program or policy support, or significant changes to heat pump technology, efficiency, and economics, only limited building electrification will occur.

Recommendations

- **Recommendation 1:** Incorporate building electrification into forecasts.
- **Recommendation 2:** Be prepared to advise policy makers on large grid impacts of electrification of new and existing homes.
- **Recommendation 3:** Revisit forecast during each IRP to incorporate adoption rate of heat pumps, changes in city codes and policies.

2. Project Background and Objectives

2.1 Decarbonization Context

States and cities across North America have set ambitious decarbonization goals, which are now being turned into policy, including decarbonization objectives for the electric grid, transportation, and buildings. Building decarbonization across the continent has focused on two parts: energy efficiency[4] and electrification. In its most recent long term Integrated Resource Plan (IRP), Platte River Power Authority (Platte River) forecasted a dramatically reduced carbon footprint from its generation portfolio, achieving over 90% decarbonization by 2031. Given the reduced carbon intensity of its generation portfolio, Platte River and member communities have identified the opportunity for electrifying buildings to further reduce end-point fossil fuel consumption and associated greenhouse gas emissions. Further, member communities are also developing action plans and committing themselves to even deeper reductions in fossil fuel consumption and have identified building electrification as one of the key solutions to achieving this goal.

2.2 Objectives

Platte River, as part of resource planning efforts, sought to understand the long-term impacts of building electrification on the Platte River electric system. In the context of this study, building electrification refers to the increased electricity load in homes/buildings from customers' conversion from fossil fuels (natural gas, propane, or other) to electric power for existing and new homes/buildings. The study covers residential and commercial customers being served by Platte River's owner communities of Fort Collins, Longmont, Loveland, and Estes Park, Colorado.

The goal of this study was to provide Platte River decision makers with data driven insights to understand the range of impacts of future building electrification on Platte River's system. Additionally, this study sought to address the impacts of various policy scenarios that could increase building electrification adoption rates. This effort was also an extension of the residential building electrification study Apex conducted for member cities Fort Collins and Longmont.[5]

Building electrification presents both opportunities and risks to ratepayers, Platte River Power and its associated utilities as shown in Table 1 below. The risks and opportunities identified below were one of the primary drivers for Platte River to conduct this study.

[4] Platte River and member communities have successful programs promoting energy efficiency.

[5] The study excluded industrial processes.

Table 1. Building Electrification Opportunities and Risks

Entity	Opportunities	Risks
Utility and Program Administrator	• Increased electricity sales • New load flexibility grid benefits • Environmental benefits	• New peak loads • Customer distrust of new technologies
Ratepayers and Participants	• Saving money on energy services • Improved comfort[6] • Environmental benefits • Jobs	• Increased peak demands leading to increasing rates[7] • Failure of critical life/safety infrastructure[8]

In order to understand the impacts of building electrification, Platte River developed a detailed list of study objectives. The locations of the results of these study objectives can be found in Table 2 below.

Table 2. Summary of the Building Electrification Study Objectives and Report Location

Category	Objective	Location
Measure-Level Electricity Impacts	Annual Electricity Impacts	Report Section 4.5
Measure-Level Electricity Impacts	Peak Electricity Impacts	Report Section 4.5
Measure-Level Electricity Impacts	Load shapes in 12x2x24 format	Data Spreadsheet Appendix: BE EE Stock Hourly Forecast Results_2022-01-18.xlsx
Measure-Level Electricity Impacts	End Use Load shapes for heating, hot water, laundry, cooking in 12x2x24 format	Data spreadsheet Appendix: Forecast Model Results.xlsx
Measure-Level Electricity Impacts	Temperature relationship of peak impacts (e.g., peak load as f(hourly temp, last 12 hours temp, last 48 hours temp))	Report Section 6.7
Measure-Level Costs and Benefits	Incremental cost of equipment in different applications (Replace on burnout (ROB)/Retrofit (RET)/New Construction (NEW))	Data Spreadsheet Appendix: Forecast Model Results.xlsx
Measure-Level Costs and Benefits	Fuel Savings	Report Section 4.5

[6] Heat pumps installed for heating in homes without existing central air conditioning receive a significant cooling comfort benefit.

[7] In most of the country, adding central air conditioning loads has increased rates, because they increase peak demand more than annual energy consumption. The same risk is possible for some electrification measures, especially when the system peak starts occurring in Winter???.

[8] Reliance on electricity alone for heating can be problematic in the event of generation outages or derates which could result in rolling blackouts and lead to frozen pipes or worse.

Temperature Comparison	Comparison of equipment rating, building design, and utility planning temperatures	Report Section 4.3
Forecasted Adoption Impacts	Monthly peak demand (MW) and monthly energy (MWh) For each of 5 scenarios	Data spreadsheet Appendix: Forecast Model Results.xlsx
Forecasted Adoption Impacts	Description of each scenario, likelihood of local, state, and federal policy interventions, carbon tax impacts, and equipment and installation contractor availability impacts.	Report Section 3.2
Forecasted Adoption Impacts	Technical opportunity without grid constraints	Data Spreadsheet Appendix: Forecast Model Results.xlsx
Forecasted Adoption Impacts	Technical opportunity with grid constraints	Data Spreadsheet Appendix: Forecast Model Results.xlsx
Forecasted Adoption Impacts	Fraction of transformers requiring upgrade in each of the high adoption and technical potential cases	Distribution Equipment Impacts Tool
Forecasted Adoption Impacts	Extreme temperature peak demand impacts for each forecast and technical scenario	Report Section 6.3, Data Spreadsheet Appendix: Forecast Model Results.xlsx
Load flexibility Impacts	Short duration and medium duration impacts	Report Section 6.6
Load flexibility Impacts	Technical demand response potential by month by year	Report Section 6.6

2.3 Definitions

The following are the definitions for each of the major concepts included throughout this report.

- **Equipment stock** – the installed stock of equipment present in the study area as of a specific time, including the mix of equipment characteristics.
- **Equipment saturation** – the fraction of the building stock or a portion of the building stock that has equipment with a given set of characteristics.
- **Market penetration** or **market share** – the share of equipment sold for a particular application at a specific time that has a given set of characteristics.
- **Building electrification impacts** – any change in the demand for electricity or fuel over any time period (e.g., yearly, monthly, hourly), caused by building electrification.
- **Technical opportunity for building electrification** – the size of building electrification impacts that is technically possible if all building fuel end uses at a given time are converted to electricity.
- **Stock turnover model** – a model that tallies all of the equipment stocks and flows to forecast the change in the equipment stock over time. Includes three pathways:

- **Replace on Burnout (ROB)** – assumes equipment is replaced as it meets end of life with baseline of alternative code-minimum equipment.
- **Retrofit (RET)** – assumes equipment is replaced before end of life with some remaining useful life, so uses a dual baseline of existing equipment and new code-minimum equipment.
- **New Construction (NEW or NC)** – assumes equipment is installed as part of new construction, assumes code-minimum equipment baseline.

〉 **Building electrification measure** – a change in the equipment stock from a fossil-fueled piece of equipment to an electricity-fueled piece of equipment.

〉 **Measure characterization** – the process of defining the size, efficiency, and usage of the baseline and efficient pieces of equipment in a building electrification measure, resulting in estimates of per unit building electrification impacts and costs.

〉 **Measure List -** The forecast includes a group of 16 key electrification measures used in this analysis. The measure characteristics include sector, measure name, end use, baseline equipment, efficient equipment, the degree of gas displacement, and market path. Table 3 shows each of these characteristics.

Table 3. Composition of Key Measures Use in Analysis

Sector	Measure	End Use	Base Equipment	EE Equipment	Gas Displacement	Market Path
Residential	ResHeatBoilerPartial50	Space Heating	Boiler	Ductless HP	50%	ROB/NC/RET
	ResHeatBoilerFull	Space Heating	Boiler	Ductless HP	100%	ROB/NC/RET
	ResHeatFurnPartial50	Space Heating	Furnace / AC	Central HP	50%	ROB/NC/RET
	ResHeatFurnPartial80	Space Heating	Furnace / AC	Central HP	80%	ROB/NC/RET
	ResHeatFurnFull	Space Heating	Furnace / AC	Central HP	100%	ROB/NC/RET
	ResDHW-Gas	Water Heating	Gas Water Heater	Heat Pump Water Heater (HPWH)	100%	ROB/NC/RET
	ResCooking	Cooking	Gas Stove	Induction Cooking	100%	ROB/NC/RET
	ResAllElectricNCStd	Whole Home	IECC 2021[9] New construction w gas service	New construction w/out gas service	100%	NC
	ResAllElectricNCHE	Whole Home	IECC 2021 New construction w gas service	High efficiency new construction w/out gas service	100%	NC
Commercial	CIBuiltUpPartial50	Space Heating	Boiler / Chiller / Air Handling Unit	Variable refrigerant flow heat pumps	50%	ROB/NC/RET

[9] IECC 2021 is likely to be adopted soon by Fort Collins and other communities. The code sets the minimum energy conservation-related building construction standards for residential new construction. 2021 International Energy Conservation Code (IECC) - CHAPTER 1 (iccsafe.org)

	CIBuiltUpFull	Space Heating	Boiler / Chiller / Air Handling Unit	Variable refrigerant flow heat pumps	100%	ROB/NC/RET
	CIHeatRTUPartial50	Space Heating	Gas Roof Top Unit	HP Roof Top Unit	50%	ROB/NC/RET
	CIHeatRTUPartial80	Space Heating	Gas Roof Top Unit	HP Roof Top Unit	80%	ROB/NC/RET
	CIHeatRTUFull	Space Heating	Gas Roof Top Unit	HP Roof Top Unit	100%	ROB/NC/RET
	CIDHW-Gas	Water Heating	Gas Water Heater	HPWH	100%	ROB/NC/RET
	CICooking	Cooking	Composite Gas Cooking	Composite Electric Cooking	100%	ROB/NC/RET

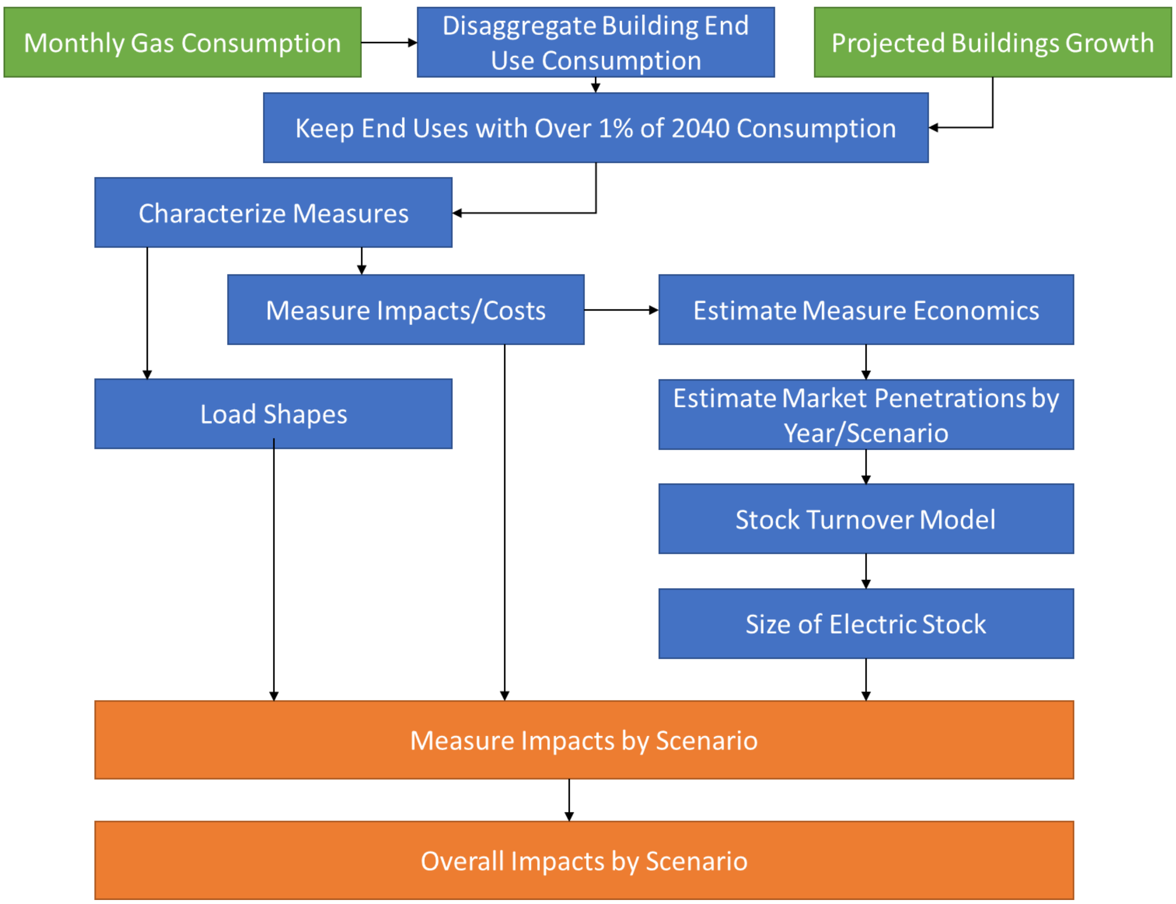
3. Approach

This section describes the overall approach, development of forecast scenarios, and caveats associated with the building electrification forecast.

3.1 Overall approach

To estimate the near term and long-range building electrification impacts to member communities and Platte River's electric system, Apex forecasted the building electrification impact based on several key scenarios developed in concert with the Platte River project team. Figure 1 shows the overall forecasting approach, with each primary step appearing in the figure. Additional descriptions for each of the primary steps are found below the figure.

Figure 1. Overall Approach



- **Monthly Gas Consumption**: We relied on actual community-wide natural gas consumption as the starting point. This data was obtained from member community 2020 natural gas consumption. Monthly data was available for Fort Collins and Longmont, while annual data was available for Loveland and Estes Park.

- **End Use Disaggregation**: We disaggregated the residential and commercial natural gas load based on the monthly consumption in Fort Collins and Longmont, splitting the consumption into heating and non-heating, then splitting the non-heating consumption up based on RECS[10] and CBECS[11] end use shares of non-heating. This is a critical step to estimate the technical opportunity for each of the end uses (space heating, water heating, cooking, etc.).
- **Keep End Uses with over 1% of 2040 Fossil Fuel Consumption:** The team estimated 2040 fossil fuel consumption by end use, assuming a consistent 1.8% annual growth rate in the building stock,[12] with efficiency levels fixed at 2020 levels, with baseline consumption estimated using disaggregated 2020 natural gas consumption data at the community level. End uses making up at least 1% of 2040 fossil fuel consumption were included for further analysis.
- **Measure Characterization:** Apex previously designed electrification measures via our work for the cities of Fort Collins and Longmont. We limited the building electrification forecast to aggregate electrification measures representing each of the most likely equipment types to be installed (distilling the 143 unique measures in the original residential-only analysis to a group of 16 composite measures).
- **Measure Impacts**: Similar to characterization, Apex also compiled both baseline and electrification equipment costs, fuel and electric energy and demand impacts, and measure life. We used both the measure characterization and impacts to run cost effectiveness analysis with resulting measure economics (net benefits and cost per ton of avoided carbon).
- **Load shapes**: Fort Collins provided data to National Renewable Energy Laboratory (NREL) to support a national load shape development process. Apex used the resulting NREL load shape database[13] and adapted the Fort Collins shapes for this analysis. For most end uses, the load shapes were used directly after manipulation to normalize to a unitized load shape. For residential and commercial heat pumps with varying switchover temperatures and efficiency, a separate equipment model was used to turn the estimated heating thermal loads from the NREL study into estimated heat pump consumption values. These heat pump shapes were then normalized into a unitized load shape.
- **Forecast Adoption and Turnover:** the final step in the electrification process was to forecast the anticipated adoption rates for each equipment type assuming demand derived from replace-on-burnout (ROB), new construction (NEW), and early replacement (RET) market pathways. We differentiated adoption across the equipment types and customized for each of the seven

[10] Residential End Use Consumption Survey, US Energy Information Agency, https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#undefined

[11] Commercial End Use Consumption Survey, US Energy Information Agency, https://www.eia.gov/consumption/commercial/

[12] Housing and Urban Development Fort Collins Comprehensive Housing Market Analysis, Aug 1, 2017. https://www.huduser.gov/portal/publications/pdf/FortCollins-CO-comp-2017.pdf.

[13] End-Use Load Profiles for the U.S. Building Stock | Buildings | NREL

different scenarios (reviewed below). We based adoption rates on a combination of naturally occurring demand, program support and incentives, adoption of code and other regulatory requirements.

3.2 Scenario Definitions

Through a series of stakeholder meetings, Apex and Platte River staff settled on seven different adoption scenarios to model. The seven scenarios span a wide range of possible policy and market evolution pathways?. The team did not model a null scenario where no significant building electrification takes place, but there is a possibility that this scenario may still occur. The scenarios developed for this analysis include the following:

- **Low adoption**: limited to enhanced utility incentives
- **Medium adoption**: low plus code requirements for heat pumps
- **High adoption**: medium plus carbon tax and all electric new construction code
- **High adoption + gas phase-out**: high plus gas equipment phase out
- **High adoption + envelope improvements**: high plus envelope improvements
- **Technical adoption – constrained**: code limits on electric resistance heat sizing
- **Technical adoption – unconstrained**: unconstrained full adoption

Table 2 below summarizes the modeled adoption scenarios.[14] The top three scenarios (bordered in red) represented the Low, Medium, and High scenarios used for all of the results reported throughout this report. The low or medium scenarios appear to be the most likely median scenario, but all three of these scenarios, plus the null scenario with zero adoption, constitute plausible future scenarios with a significant likelihood of occurrence.

Table 4. Modeled Adoption scenarios

Modeled Scenario	1. Low adoption	2. Medium adoption	3. High adoption	4. High adoption + gas phaseout	5. High adoption + envelope
Utility Incentive Levels	Medium	Medium	Medium	Medium	Medium
Full Electrification	Low	Low	Medium	High	High
Carbon Tax	None	None	2025	2025	2025
Code requires heat pumps in lieu of AC in NC	None	2025	2025	2025	2025
Code requires heat pumps in lieu of AC in ROB/ Retrofit	None	2028	2028	2028	2028
All New Construction all electric	None	None	2030	2030	2030

[14] Note the two technical potential scenarios are excluded from this table because they rely on a completely different set of assumptions.

Full phase out of gas equipment	None	None	None	2035	None
Envelope Improvement	Low	Low	Low	Low	High

3.3 Forecasting Caveats and Sources of Uncertainty

Apex leveraged the most accurate and region-specific data available for this analysis and decided on a more conservative series of assumptions for the electrification forecast. However, forecasting carries substantial uncertainty, especially for new technology applications, like building electrification in Colorado. While we sought to address this uncertainty by developing seven different scenarios, there are still several areas that could affect the forecasts that should be mentioned:

- Faster adoption of all-electric new construction codes
- Slower market adoption of building electrification technology
- The retail rates of natural gas and electricity
- The advancement of higher efficiency cold climate heat pumps or other advanced space heating technologies
- Changes in the upfront cost of heat pumps versus gas equipment
- Federal or statewide regulation

Though many of the areas of uncertainty for this study are inherent in forecasting, in the future, additional data may be available to improve the accuracy of the forecast. These future data collection activities could reduce the uncertainty for this study:

- Collecting baseline residential and commercial building characteristics
- Compiling installation cost estimates for baseline and electrification equipment from a random group of regional contractors
- Secondary research on adoption rates among other early adoption locations

4. Measure Characterization Results

For the next step in this analysis, the Apex Team estimated measure-level impacts in terms of fuel savings, electricity increases, load shape of electricity increases and winter peak demand impacts by extrapolating Fort Collins and Longmont results to Platte River overall. The team had already screened residential measures for Fort Collins and Longmont and added on the high impact C&I opportunities. The forecast of total energy, demand, carbon, and other fuel impacts are based on the product of (A) the assumed per unit impacts associated with each of the primary equipment types (which are fixed per unit assumptions) and (B) the forecasted quantity of units converted to electric end use over the same timeframe. This section covers important details on the development of the measure level per unit impacts along with other considerations for electrification technologies (such as frequency of extreme temperatures and heat pump operating economics).

4.1 End Use Fossil Fuel Consumption Estimates

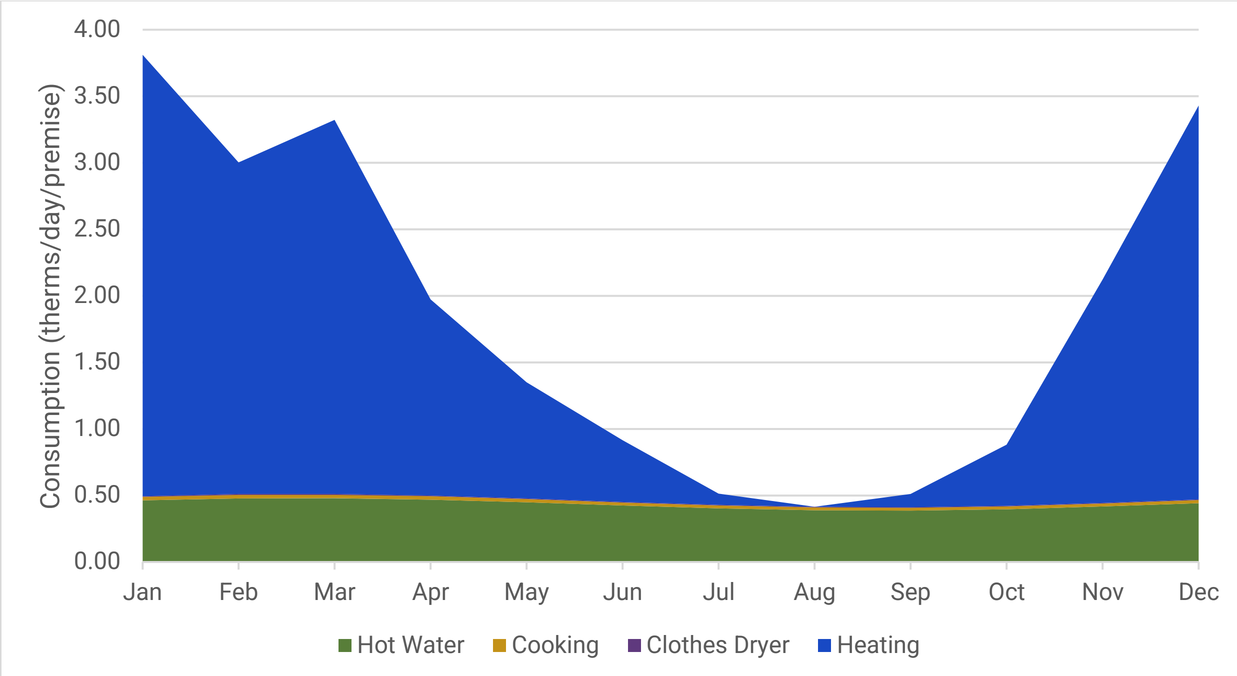
Actual loads are most strongly dependent on the existing heating/hot water/cooking load, which is a function of the building stock, occupancy, and occupant behavior. Therefore, starting with fossil fuel end use consumption estimates provides more accurate results than other methods of extrapolation. Apex staff disaggregated monthly natural gas consumption data by sector, starting by estimating heating versus non-heating data from the monthly variability, then using Residential Energy Consumption Survey (RECS)[15] and Commercial Building Energy Consumption Survey (CBECS)[16] data combined with a seasonal hot water load shape tool to estimate the breakdown of the non-heating consumption into individual end uses. Monthly disaggregation was completed for Fort Collins and Longmont, with these disaggregation shares then applied to annual consumption data from Loveland and Estes Park.

As shown in Figure 2, with natural gas monthly disaggregation, it's obvious that space heating makes up the vast majority of residential gas consumption.

[15] US Department of Energy, found online at https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#undefined

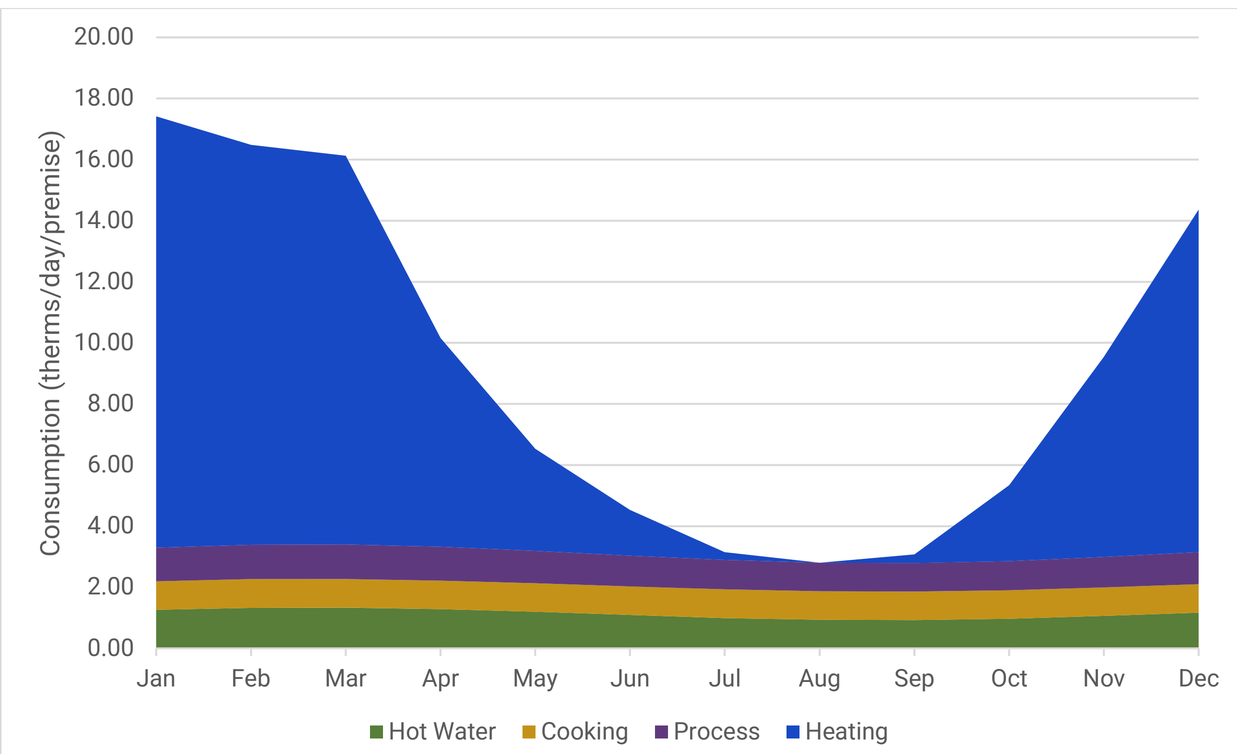
[16] US Department of Energy, found online at https://www.eia.gov/consumption/commercial/

Figure 2. Fort Collins Residential Gas Consumption Disaggregation



The monthly disaggregation also shows a high proportion of heating gas consumption in commercial accounts, as shown in Figure 3.

Figure 3. Fort Collins Commercial Gas Consumption Disaggregation



The commercial results are somewhat surprising, showing a higher proportion of space heating in commercial buildings in Platte River area than observed nationally. This could be due to a number of factors, including multifamily residential buildings or small commercial buildings with high building envelope loads making up a substantial proportion of the commercial building stock.

The process load was estimated and removed from this commercial analysis, as industrial and large commercial process loads are out of scope for this study. Better estimates of electrification of industrial and large commercial process loads can be made using site-specific assessment of industrial facilities in the area.

Apex staff then adjusted residential building consumption up by 5% to account for potential propane accounts. This proportion is unknown, but likely to be small, given the availability of gas in most areas of the Platte River communities. Apex staff estimated end use consumption for non-metered end uses, including forklifts and lawn and garden equipment, using national data scaled to Platte River community population. Last, Apex staff estimated 2040 consumption by applying fixed growth factors consistent with recent growth trends.

4.2 Measure Selection

Apex staff worked with Platte River to settle on a final list of end use technology variants, based on the building electrification technologies that apply to the largest source of projected 2040 building fossil fuel consumption. As shown in Table 2, the team removed all end uses with less than 1% of emissions from modeling consideration, opting to focus more attention on the most impactful end uses. Electrification of space heating alone represents approximately three-quarters of the high level technical potential for 2040 GHG reduction, driven primarily by residential space heating.

Table 5. Projected 2040 Fossil Fuel Emissions by Sector and End Use

Sector	End Use	Percent of 2040 Fossil Fuel GHG Emissions	Included in PRPA Forecast
Residential	**Space Heating**	**51.8%**	**Yes**
Residential	Water Heating	12.5%	Yes
Residential	Cooking	1.7%	Yes
Residential	Lawn and Garden	0.9%	No
Residential	Clothes Dryer	0.5%	No
Commercial	**Space Heating**	**23.6%**	**Yes**
Commercial	Cooking	4.7%	Yes
Commercial	Water Heating	2.9%	Yes
Commercial	Forklifts	0.8%	No
Commercial	Lawn and Garden	0.6%	No

There was significant benefit in focusing the more in-depth analysis on the measures that are likely to have the largest technical opportunity in terms of increased electricity loads. For example, residential space heating represents more than half of the projected 2040 building fossil fuel consumption, while residential cooking represents less than 1%. As a result, Apex began the process by screening down to the prioritzied list of measures based on the technical opportunity. We determined only those measures contributing at least 1% of total technical opportunity to be included in further analysis.

4.3 Extreme Cold Temperature Frequency

Apex conducted a review of Fort Collins weather records from the last 130 years to estimate the frequency of extreme weather events that have been observed. Knowing the extent and duration of extreme cold weather events is an important consideration for building electrification efforts, as it drives the need for backup heat, beyond performance at the ASHRAE(?) design temperature of 0 degrees, which corresponds with the lowest temperature that get exceeded almost every year. Apex analyzed the occurrence of three different kinds of extreme cold weather events:

- **Short duration**: Lowest temperature observed each year
- **Medium duration**: Lowest average temperature over a two-day period
- **Long duration**: Lowest average temperature over a five-day period

The minimum temperature observed during the February 2021 extreme cold event was -11degree F. As shown in Table 4, the temperature has reached -10 or colder, 17 years since 1980. Even colder temperatures have been observed in the past. Since regular heat pumps cease to work below ~0 degrees and even cold climate heat pumps currently cease to work below -15 degrees, this shows that backup systems are likely to be required, even for cold climate heat pumps.

Table 6. Frequency of Absolute Minimum Temperature Occurrence in Fort Collins

Percentile (year frequency)	Temperature (degrees F)	Last Year of Occurrence	Number of years since 1980
95% (19 in 20)	-3	2021	33
90% (9 in 10)	-5	2021	32
75% (3 in 4)	-10	2021	17
50% (1 in 2)	-15	2017	8
25% (1 in 4)	-22	1990	2
10% (1 in 10)	-30	1962	0
5% (1 in 20)	-31	1962	0

Over the last 130 years, the 1-year-in-10 extreme 2-day cold weather event has had an average temperature of -12 degrees, which has also occurred twice since 1980, as shown in Table 5. This is much colder than the coldest 2-day average temperature observed in February 2021, which was -1 degree.

Table 7. Frequency of Lowest 2-day Average Temperature in Fort Collins

Percentile (year frequency)	Temperature (degrees F)	Last Year of Occurrence	Number of years since 1980
95% (19 in 20)	12	2021	36
90% (9 in 10)	11	2021	33
75% (3 in 4)	7	2021	25
50% (1 in 2)	1	2021	13
25% (1 in 4)	-5	1990	3
10% (1 in 10)	-12	1990	2
5% (1 in 20)	-14	1989	1

Likewise, the 1-year-in-10 extreme 5-day cold weather event had an average temperature of -3 degrees, which has occurred 3 times since 1980. This is also colder than the coldest 5-day average temperature observed in February 2021, which was 4 degrees.

Table 8. Frequency of Lowest 5-day Average Temperature in Fort Collins

Percentile (year frequency)	Temperature	Last Year of Occurrence	Number of years since 1980
95% (19 in 20)	19	2021	36
90% (9 in 10)	17	2021	33
75% (3 in 4)	14	2021	23
50% (1 in 2)	9	2021	15
25% (1 in 4)	3	1998	8
10% (1 in 10)	-3	1990	3
5% (1 in 20)	-7	1989	2

4.4 Heat Pump Operating Economics

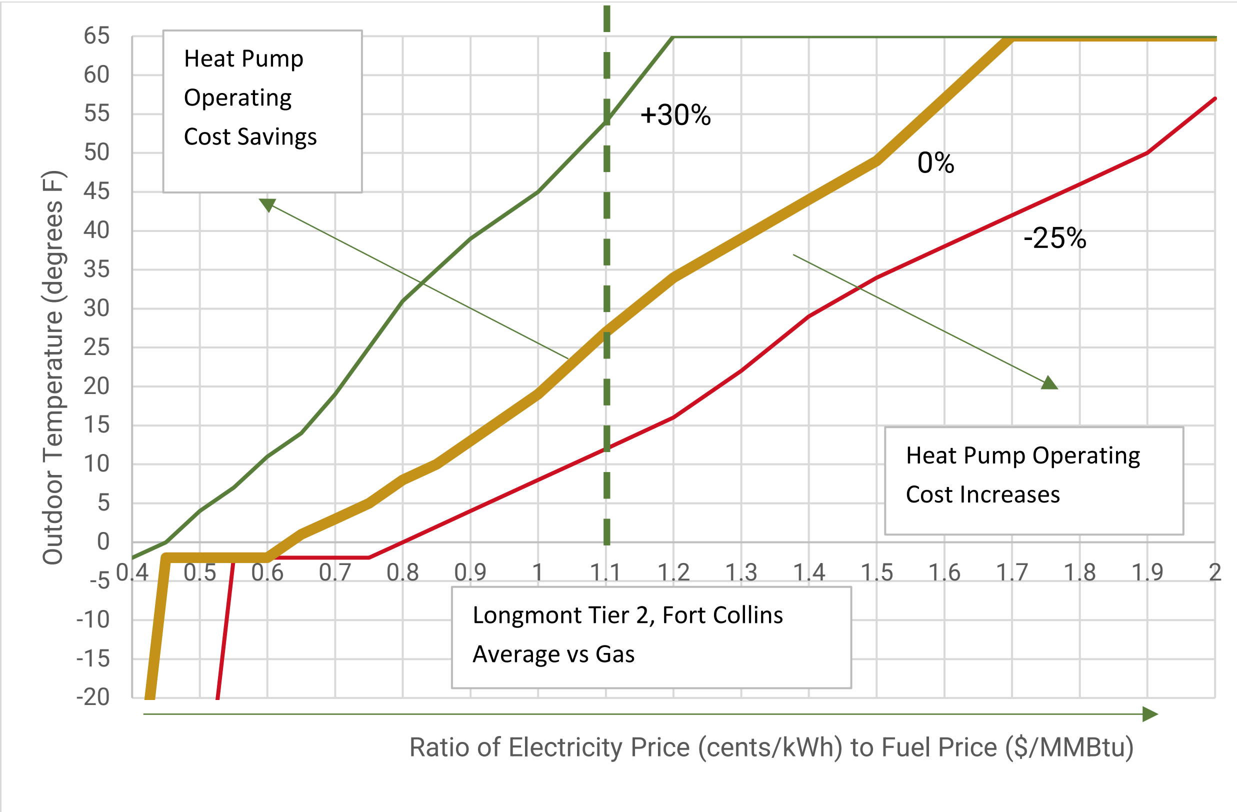
As identified in the measure screen, residential space heating with heat pumps represents the largest opportunity for building electrification. The operation of heat pumps has three key features:

1. As the temperature drops, the heating capacity drops. Cold climate heat pumps maintain rated capacity much better than standard heat pumps, but they still lose capacity at the coldest temperatures.
2. Below a certain temperature, heat pumps do not work at all. For standard heat pumps, this occurs around 0 degrees, while some cold climate heat pumps keep running down to -15 degrees.
3. The efficiency of heat pumps declines as the temperature drops, meaning it takes more electricity to provide the same amount of heat as the temperature drops.

As a result of the efficiency drop, the economics of operating a heat pump also declines as the temperature declines. The other key driver of heat pump operating economics is the price of electricity relative to the price of gas – the lower the ratio of electricity to natural gas rates the better the heat pump operating economics.

In Figure 4 below, the gold line shows the temperature and fuel price ratio (expressed as cents/kWh for electricity divided by $/MMBtu for fuel) that results in the same cost to heat with a standard furnace or a standard heat pump. At all temperatures above that line, it's more economical to heat with a heat pump than with a furnace. At all temperatures below that line, it's more economical to heat with the furnace. For Fort Collins and Longmont, as of August, 2021, the green dashed line down the middle shows the current ratio of electricity price to gas price. These utilities both have favorable economics for operating standard heat pumps above 27 degrees. This is known as the optimal switchover temperature.

Figure 4. Standard Central Heat Pump Operating Economics as a Function of Temperature and Fuel Price Ratio



A map of operating economics for a high efficiency heat pump would look very similar, except that by using ~10% less electricity per unit of heat delivered, the economics are improved, resulting in a lower optimal switchover temperature of 20 degrees. Changing gas and electricity rates will cause the optimal switchover temperature to change over time – rates are critical to the economics of heat pump displacement of fossil-fueled heating.

The results of the Fort Collins and Longmont Building Electrification Study showed that partial displacement heat pumps had the strongest customer and societal cost-benefit results. In addition, partial displacement heat pumps delivered significant benefits to non-participant ratepayers who did not purchase heat pumps by increasing sales of electricity during off-peak times.[17]

The forecast assumes a mix of standard heat pumps with a 30-degree switchover temperature (50% of gas heat displaced), high efficiency heat pumps with a 20-degree switchover temperature (80% of gas heat displaced), and cold climate heat

[17] The utility costs of supplying electricity to a given end use are driven by the required capacity (driven by usage during peak times) and the overall energy consumption. End uses that have high energy consumption without any capacity impacts (like partial displacement heat pumps) have lower utility costs of supply, pushing rates down and benefiting non-participating customers.

pumps with full electrification (100% of gas heat displaced). The actual attainment of switchover temperatures depends on contractor installation practices and customer behavior to a lesser extent. The forecasts assumed significant contractor and customer education on the benefits of optimal switchover temperatures, but still assume a mixture of 30-degree switchover and 20-degree switchovers into the 2030s and 2040s.

4.5 Measure Unit-Level Impacts

We developed unit-level measure impacts for each measure shown in Table 9, based on current (2020) operating characteristics and assumptions. These measures are an aggregation of more than 140 unique measures modeled for the Fort Collins/Longmont Study. While the units of the residential sector measures are per home, the commercial units are not directly linked to a physical unit outside of baseline gas consumption, because the most recent baseline gas consumption for 2020 is the only measure of the size of the commercial building stock that we have accurate data for. This ensures that the forecast commercial gas consumption is properly calibrated to the baseline consumption, but this comes at the expense of having a physical measure definition that can be used in program design. Additional input details can be found in the spreadsheet appendix: Forecast Model Results.xlsx.

Table 9. Measure Unit-Level Impacts

Sector	Measure	Natural Gas Savings (therms)	Annual Energy Use (kWh)	Summer Demand (kW)	Winter Demand (kW)
Residential	ResHeatBoilerPartial50	263	1,662	0.00	0.00
	ResHeatBoilerFull	543	4,067	0.00	10.00
	ResHeatFurnPartial50	263	1,907	0.00	0.00
	ResHeatFurnPartial80	438	3,007	0.00	0.00
	ResHeatFurnFull	543	4,067	0.00	10.00
	ResDHW-Gas	125	756	0.11	0.12
	ResCooking	9	126	0.03	0.06
	ResAllElectricNCStd	677	5,309	0.17	8.70
	ResAllElectricNCHE	419	4,109	0.13	6.70
Commercial	CIBuiltUpPartial50	5,000	31,550	0.00	0.00
	CIBuiltUpFull	10,000	74,900	0.00	184.17
	CIHeatRTUPartial50	5,000	36,200	0.00	0.00
	CIHeatRTUPartial80	8,000	54,960	0.00	0.00
	CIHeatRTUFull	10,000	74,900	0.00	184.17
	CIDHW-Gas	7,351	44,541	6.62	7.04
	CICooking	10,000	137,126	36.75	67.79

5. Measure-level Forecast Impacts

This section focuses on the assumptions and processes used to develop the forecasted quantity of converted equipment units through assumed adoption rates and the resulting energy and demand impacts by measure. First, we review the adoption rates (penetration forecasts) for a selection of adoption pathways (replace on burnout versus end of life retrofit) for a selection of the major equipment types. Then, we review the equipment stock forecast, showing how this results in a growing electric equipment stock substituting for a natural gas equipment stock. The final step in presenting the measure results include the relative measure-level annual energy impacts across two distinct periods (2030 and 2040) reported for each of the sectors.

5.1 Building Electrification Equipment Penetration Forecasts

The starting point for estimating the forecasted quantity is the market share or market penetration of equipment over time across each market pathway. The total market for each piece of equipment is composed of three pathways, ordered by their contribution to the forecasted electrification stock:

- Replace-on-Burnout (ROB), e.g., when a central air conditioner fails, is it replaced with an central air conditioner or heat pump?
- New Construction (NC), e.g., when a new home is built, does a central air conditioner or heat pump get installed? OR when an existing home is adding central air conditioning for the first time does a central air conditioner or heat pump get installed?
- Retrofit/Early Retirement (RET), e.g., when somebody replaces their central air conditioner while it still works.

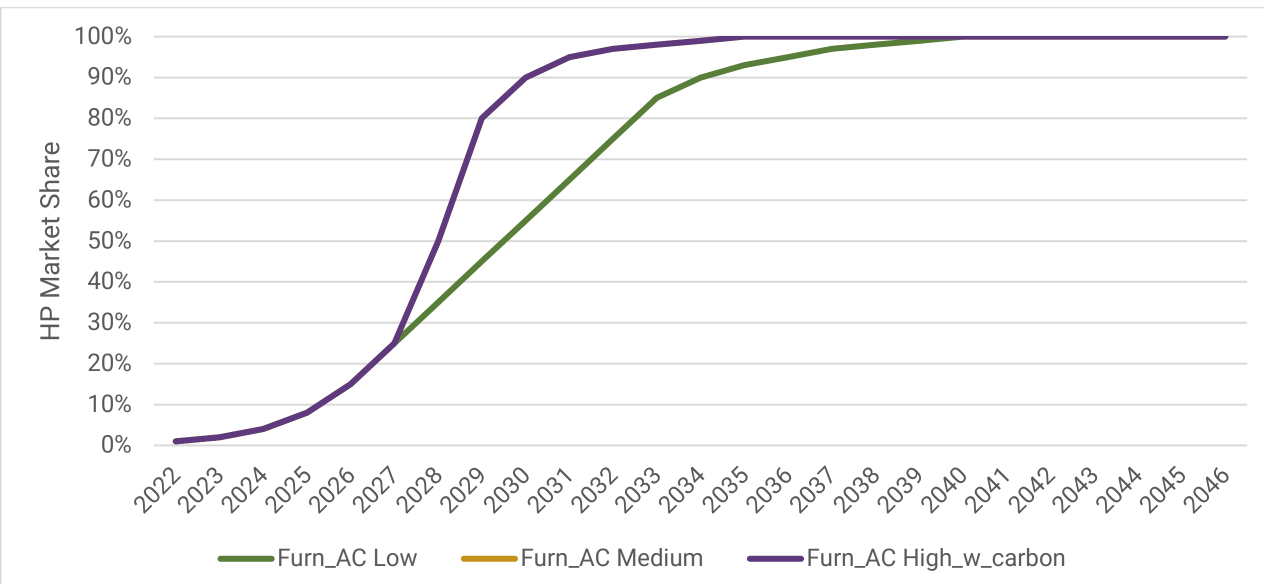
The participant cost-effectiveness has substantial differences across equipment installations in these three market pathways. In general, participant cost-effectiveness is much better for replace-on-burnout and new construction installations than for retrofit or early retirement applications. Consequently, most installations are forecast to happen through replace-on-burnout or new construction.

For heat pumps in residential applications, the most important pathway is replacement on-burn-out of central air conditioners with heat pumps, rather than replacement of furnaces with heat pumps. Replacing a burned out central air conditioner with a heat pump has very low incremental costs, while replacing a furnace costs more money. The furnaces can almost be treated independent of the central air conditioner to central heat pump conversions, except when going to a full electrification scenario.

While all of the equipment adoption rates are included in the spreadsheet appendix, we have presented results for the most important groups of measures across the primary scenarios (low, mid, high) below.

In all cases, the market share (or market adoption) is defined by the efficient market size divided by the baseline market size, which includes both base equipment and efficient equipment. The following chart (Figure 5) shows the residential heat pump adoption whereby heat pumps (efficient market size) replace burned out or retired central air conditioning systems (the base market size). The charts demonstrate the forecasted market share across the three adoption scenarios. The low case shows a relatively rapid adoption, comparable to the recent market adoption curve for LEDs, without code requirements. The medium and high cases include a code requirement for all central air conditioners to be heat pumps, starting in 2028, but then include some amount of non-compliance. The medium and high cases are largely consistent and are therefore overlapping in this chart.[18]

Figure 5. Residential Central Air Conditioning ROB Heat Pump Market Share

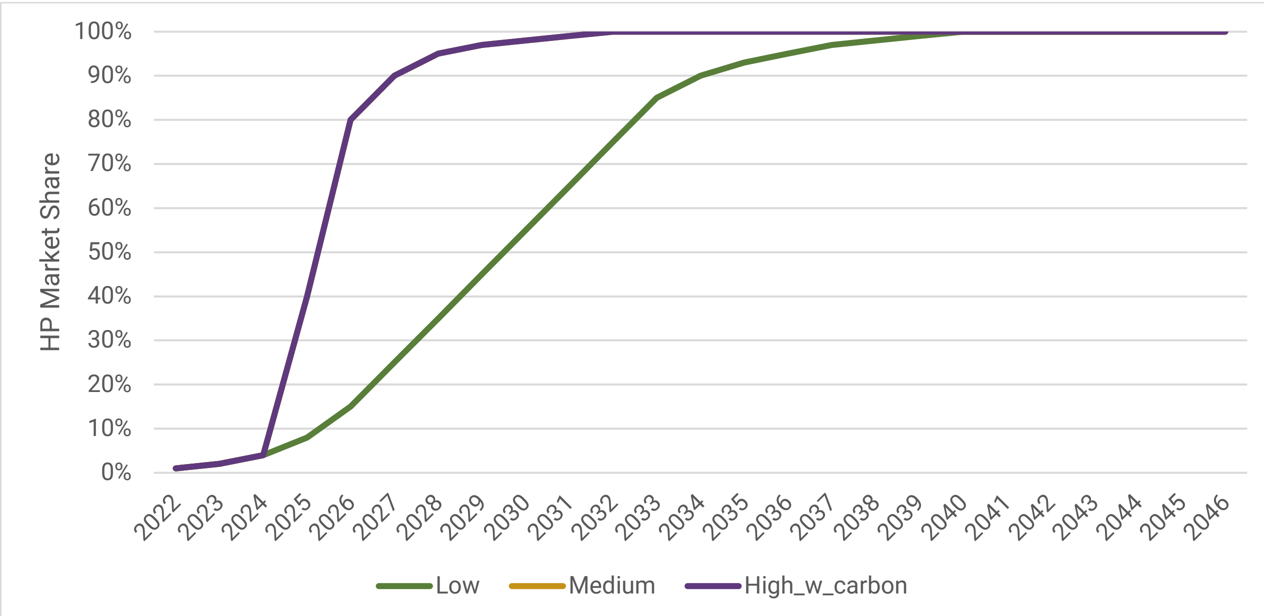


The following chart (Figure 6**Error! Not a valid bookmark self-reference.**) shows the residential heat pump adoption whereby heat pumps (efficient market size) are installed in new construction in lieu of central air conditioning systems (base market size). The chart demonstrates forecasted market share across the three adoption scenarios. Again, the medium and high cases are largely consistent and are therefore overlapping in this chart. The low case again shows an adoption curve consistent with other low incremental cost efficiency measures receiving program

[18] The only difference between the medium and high cases is the requirement for all-electric new construction after 2030. This does not change the adoption of heat pumps, only the adoption of full-displacement heat pumps.

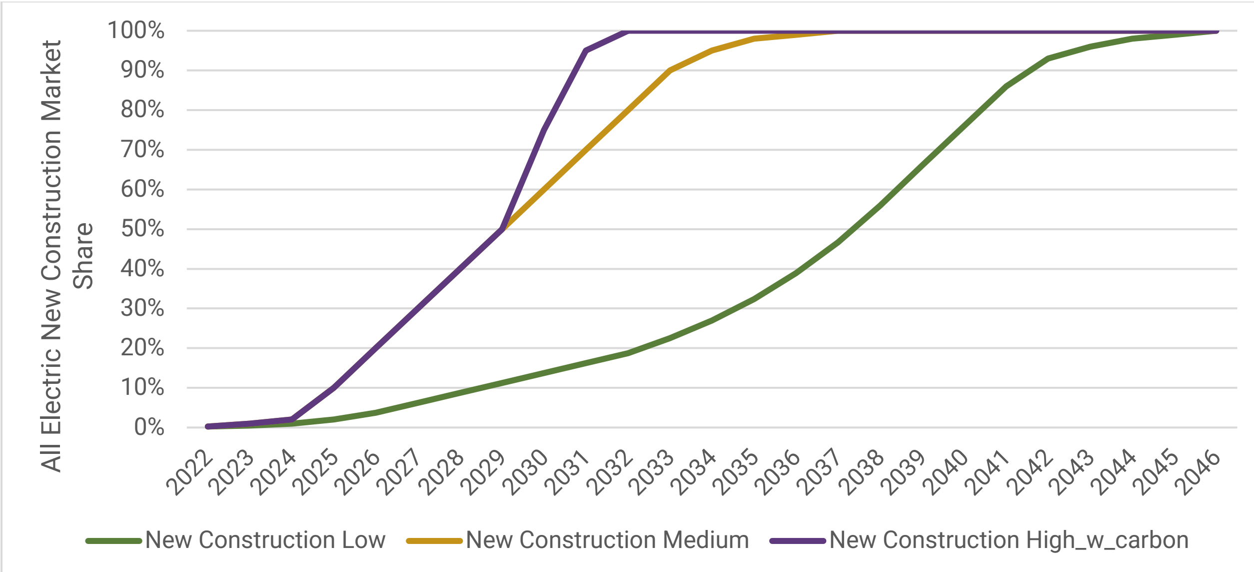
support, like LEDs, while the medium and high cases include a code requirement that all new construction with central air conditioning have a heat pump, starting in 2025, with declining non-compliance after that date.

Figure 6. Residential Central Air Conditioning New Construction Heat Pump Market Share



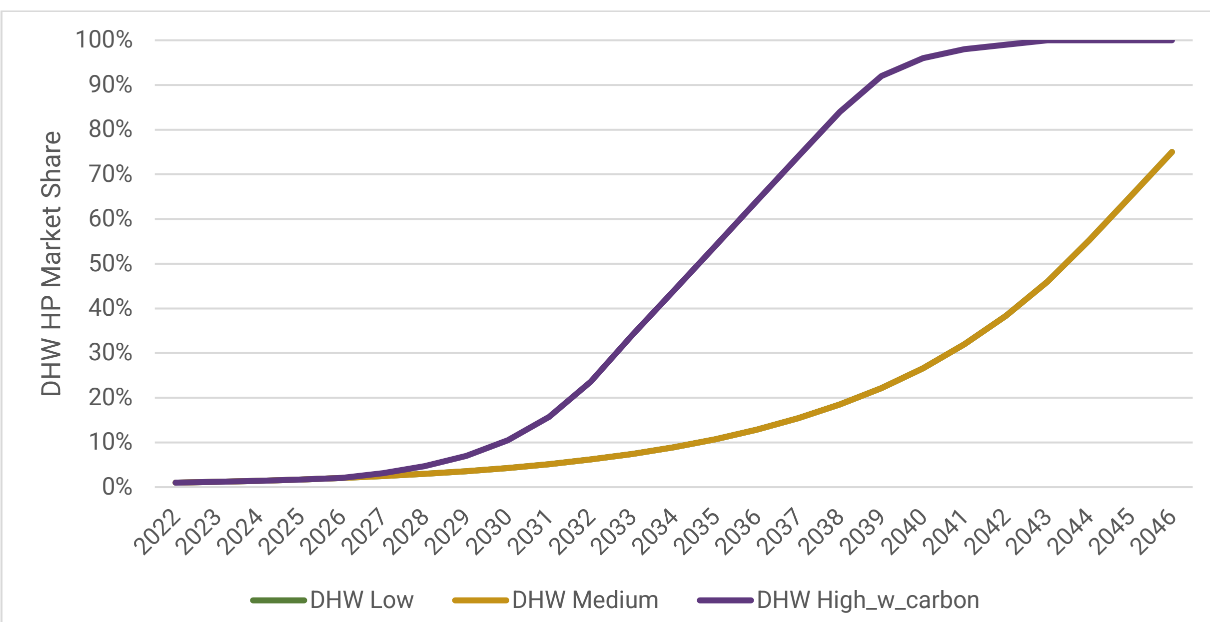
The following chart (Figure 7) shows the market share of residential all-electric new construction (homes with no gas lines present vs all homes). The chart demonstrates the forecasted market share across the three adoption scenarios and the role of codes requiring heat pumps (medium and high) and then requiring all electric new construction (high). Even the low case assumes high adoption of all-electric new construction by 2040.

Figure 7. Forecast Market Share for Residential All-Electric New Construction



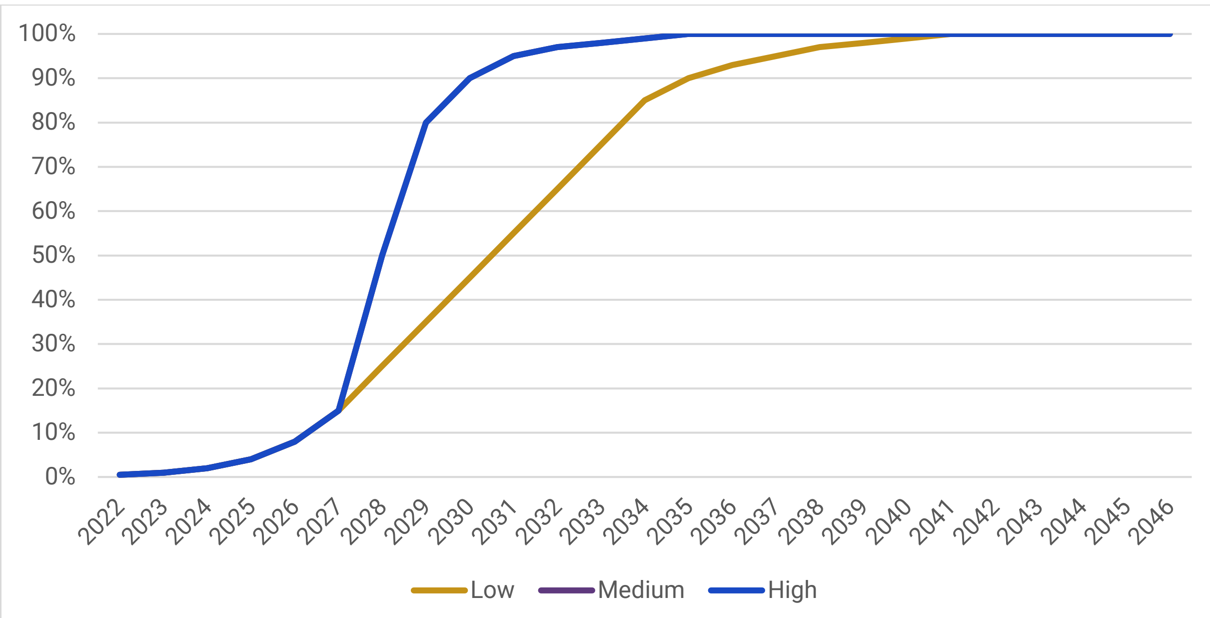
The following chart (Figure 8) shows the residential heat pump water heater adoption whereby heat pumps (efficient market size) are installed in lieu of natural gas water heating systems after a gas water heater has failed (base market size). The chart demonstrates the forecasted market share across the three adoption scenarios. Heat pump water heaters have been promoted by energy efficiency programs for many years, with little impact. As a result, the forecast assumed a slower adoption rate for heat pump hot water heaters relative to space heating electrification.

Figure 8. Market Share of Heat Pump Water Heaters in Residential Gas Water Heater ROB Applications



Though commercial and industrial buildings represent a smaller share of the forecasted electrification impacts, commercial space heating will still have a substantial impact on Platte River's system. The following chart (Figure 9) shows the commercial heat pump roof top units (RTU) adoption whereby heat pumps (efficient market size) are installed in lieu air conditioner/furnace RTU systems (base market size). The low case shows an adoption curve similar to the residential heat pump low case, but delayed a few years. The medium and high cases are overlapping and include a requirement for heat pumps in ROB applications as of 2028. The only difference between high and medium is the inclusion of a requirement for all electric new construction, starting in 2030, which does not have an impact on this part of the market.

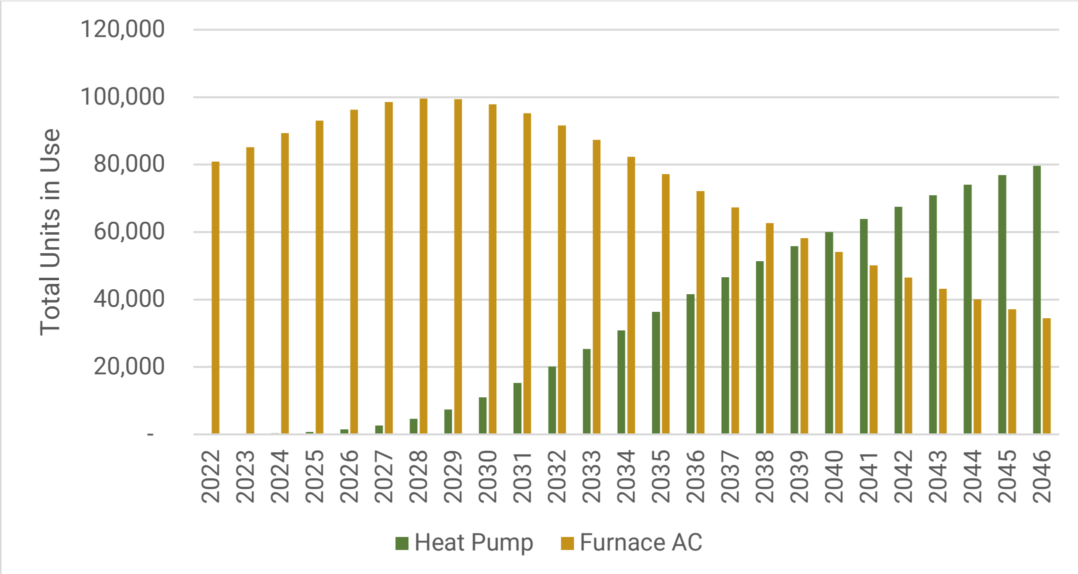
Figure 9. Commercial RTU ROB Heat Pump Market Share



5.2 Building Electrification Equipment Stock Forecast

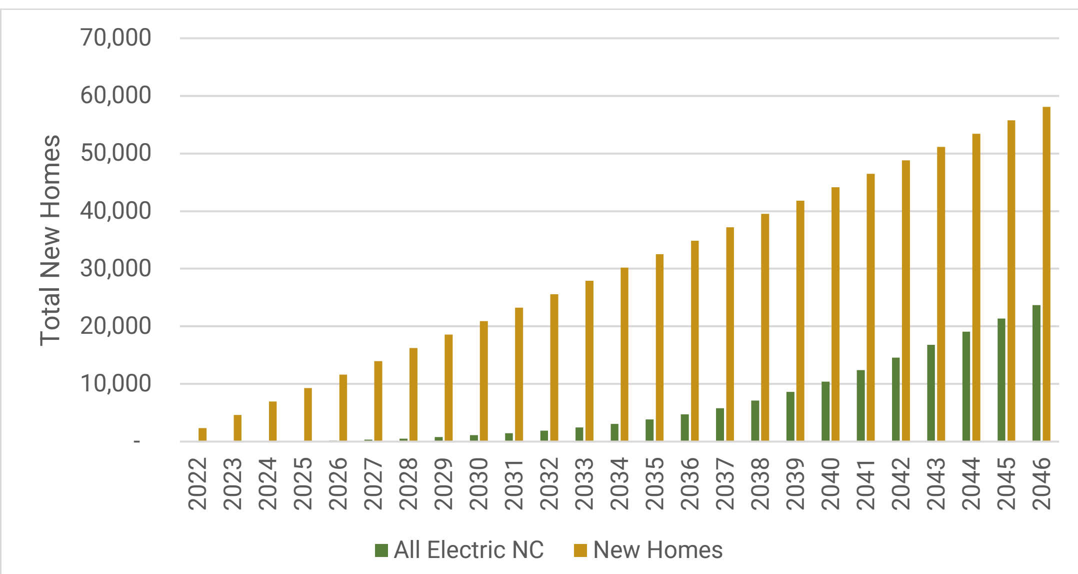
Using the stock turnover model and the market penetrations calculated above, Apex calculated the size of the increased building electrification equipment stock over time for each scenario and equipment stock. While all of the equipment stock forecasts are included in the spreadsheet appendix, we have presented results for the most important groups of measures in the low scenario below.

Figure 10. Forecasted Low Scenario Residential Furnace/AC and Heat Pump Stock



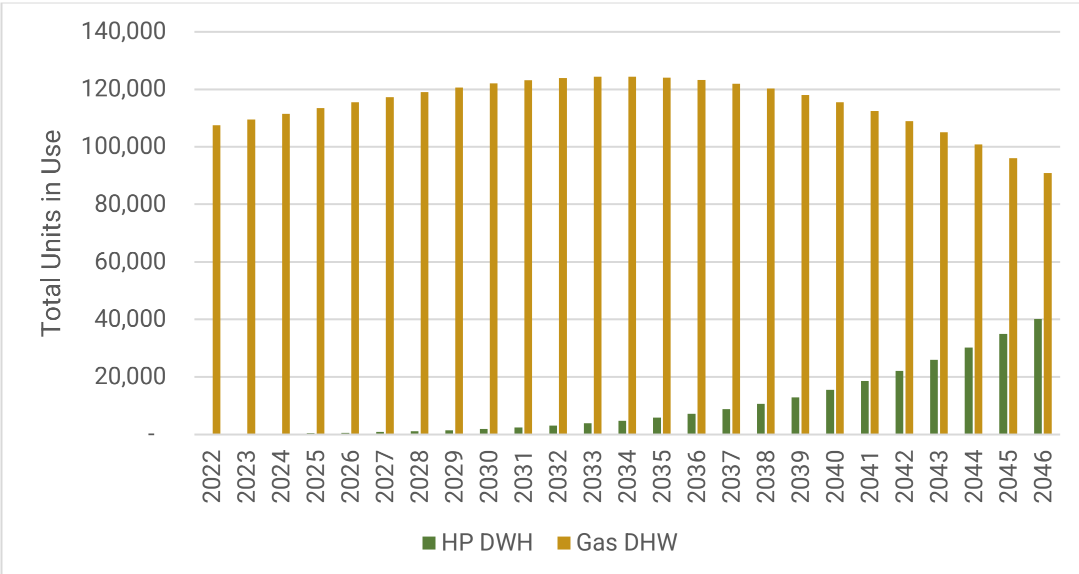
The forecast includes consistent increases in the residential building stock over time, with all electric new construction becoming more prevalent after 2030, as shown in Figure 11.

Figure 11. Forecasted Residential New Construction and Low Scenario All-Electric New Construction Homes



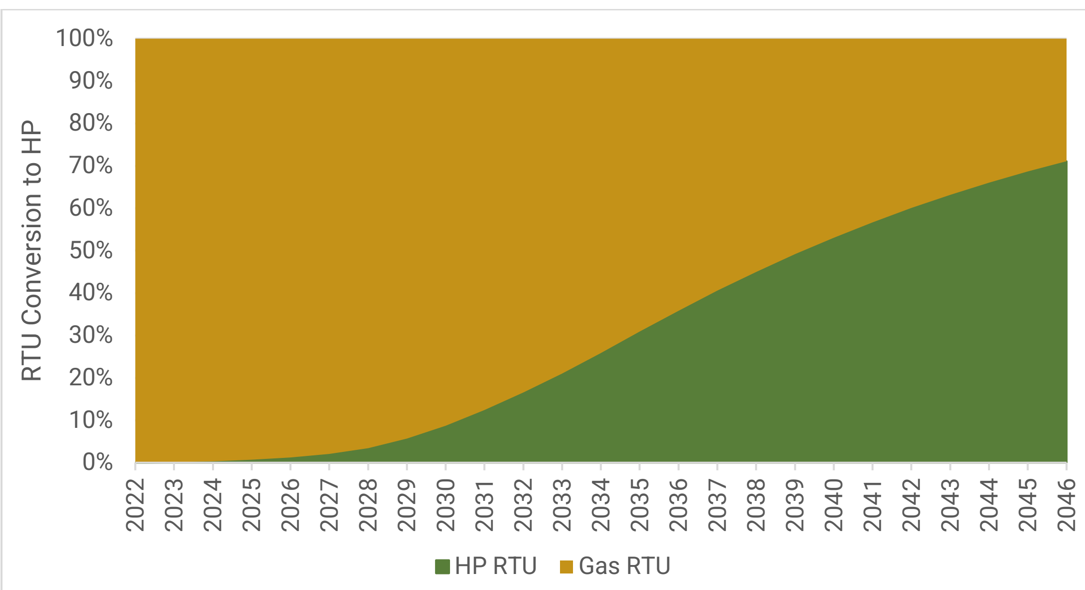
The forecast projects very little heat pump water heater adoption in the low scenario until after 2030, with the total installed stock of natural gas water heaters rising into the 2030s, after which time the heat pump water heater starts rising more rapidly, as shown in Figure 12.

Figure 12. Forecasted Residential Natural Gas Domestic Hot Water and Heat Pump Hot Water Heaters



For commercial space heating applications, the number of units does not mean as much, so we instead modeled the share of the market consumption over time, which is equivalent to the saturation. Figure 13 shows the saturation of heat pumps (EE Equipment) vs furnace/AC RTUs (standard equipment) over time. The forecast shows increasing saturation of heat pumps after 2030.

Figure 13. Commercial RTU Saturation Forecast - Low Adoption



5.3 Building Electrification Impacts by Measure

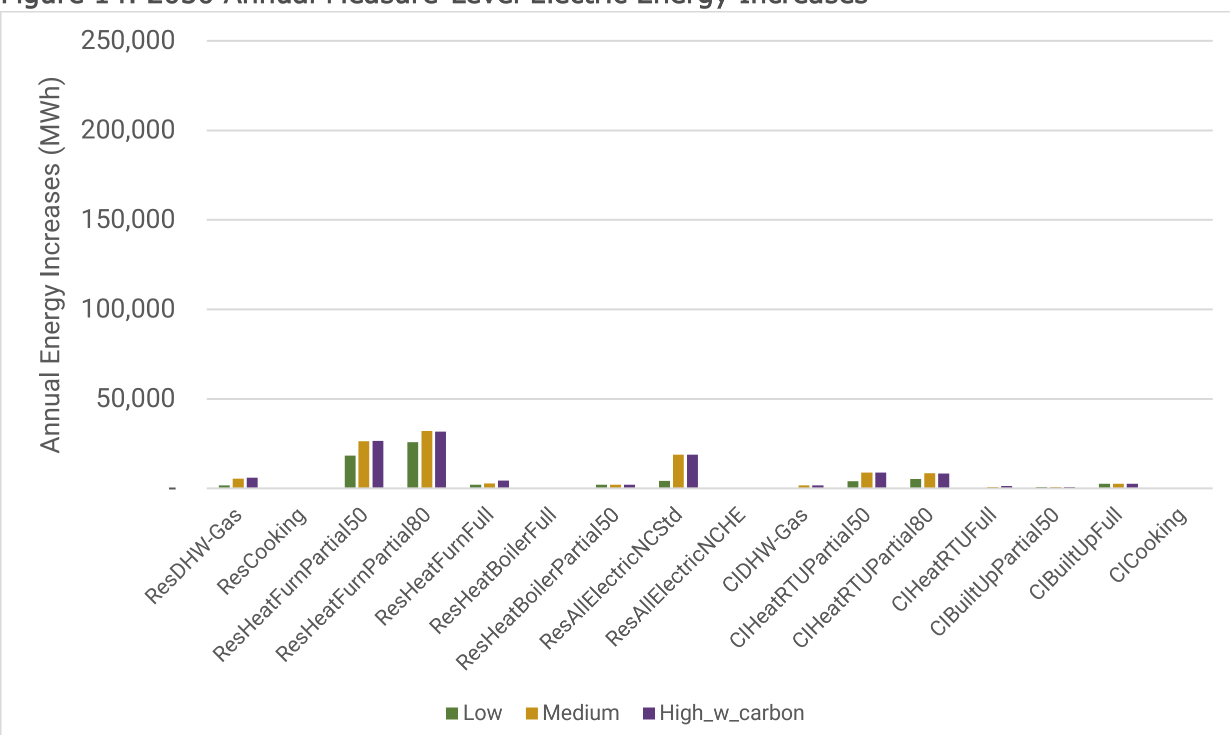
The team applied the impacts and load shapes[19] by measure to estimate the unitized impact of a given technology. To develop the total impacts for each scenario, we then applied the results of the stock model of the uptake of the technologies within Platte River territory over time (e.g. codes requiring heat pump capability for new air conditioners, new hot water heater standards, carbon tax, etc.). As a final step in the forecast process, we applied differing adoption rates with forecasts out to 2046, by measure.

Figure 14 and Figure 15 show the low, medium, and high scenario incremental electric energy consumption by measure for 2030 and 2040, respectively..

Key Finding: Partial electrification of residential furnaces, all-electric residential new construction, and commercial RTUs cause the largest electric energy increases.

The results show that the partial electrification of residential furnaces (ResHeatFurnPartial50 and ResHeatFurnPartial80), building of all-electric new homes (ResAllElectricNCStd) and partial electrification of commercial RTUs (CIHeatRTUPartial50 and CIHeatRTUPartial80) have the largest impacts across all three scenarios.

Figure 14. 2030 Annual Measure-Level Electric Energy Increases



[19] We have good residential and commercial building load shapes available from an ongoing NREL study that we participate in.

Figure 15. 2040 Annual Measure-Level Electric Energy Increases

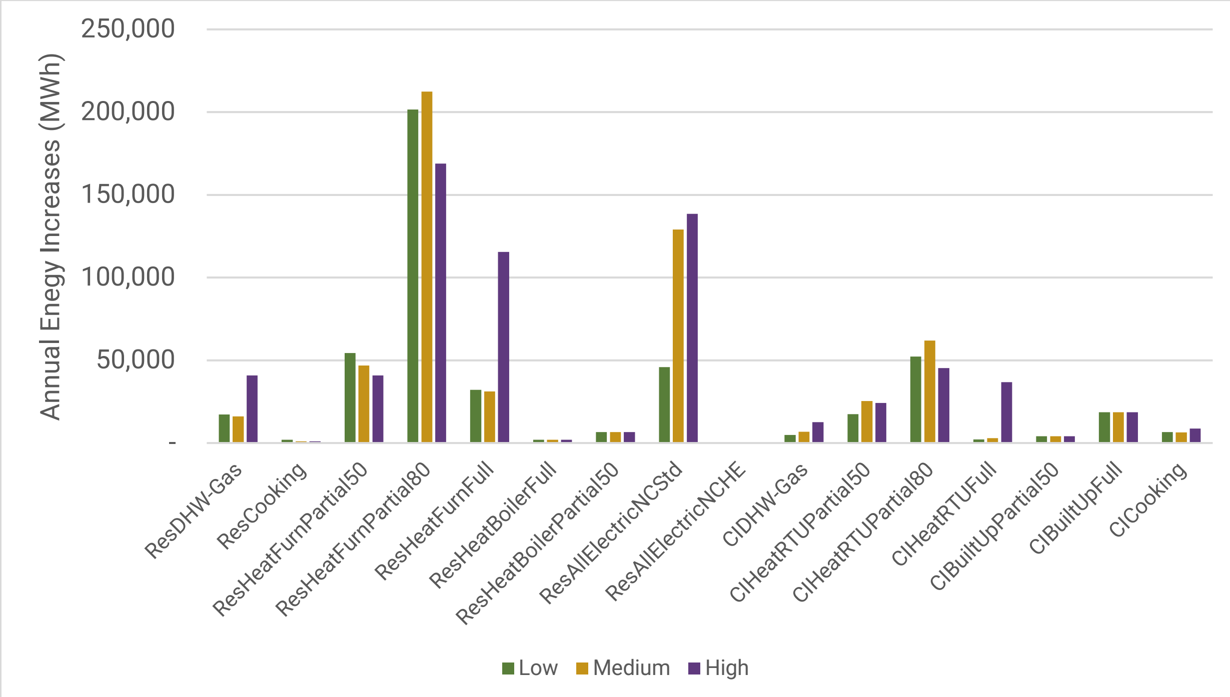


Figure 16 and Figure 17 show the forecast winter peak demand increases by measure.

Key finding: Full electrification of residential space heating, commercial space heating, and residential new construction will cause large increases in winter peak demand.

Partial electrification of residential and commercial heating will have zero impact on winter peak demand, because when the weather gets extremely cold, electric heat pump will cease operation and the backup gas heating equipment will start heating. However, the full heating electrification measures (ResHeatFurnFull, CIHeatRTUFull, and CIBuiltUPFull) will continue to run heat pumps or supplement with electric resistance heat during winter peak conditions. These measures, plus the all-electric residential new construction measure (ResAllElectricNCStd) cause large winter peak demand increases by 2040.

Figure 16. 2030 Annual Measure-Level Electric Winter Demand Increases

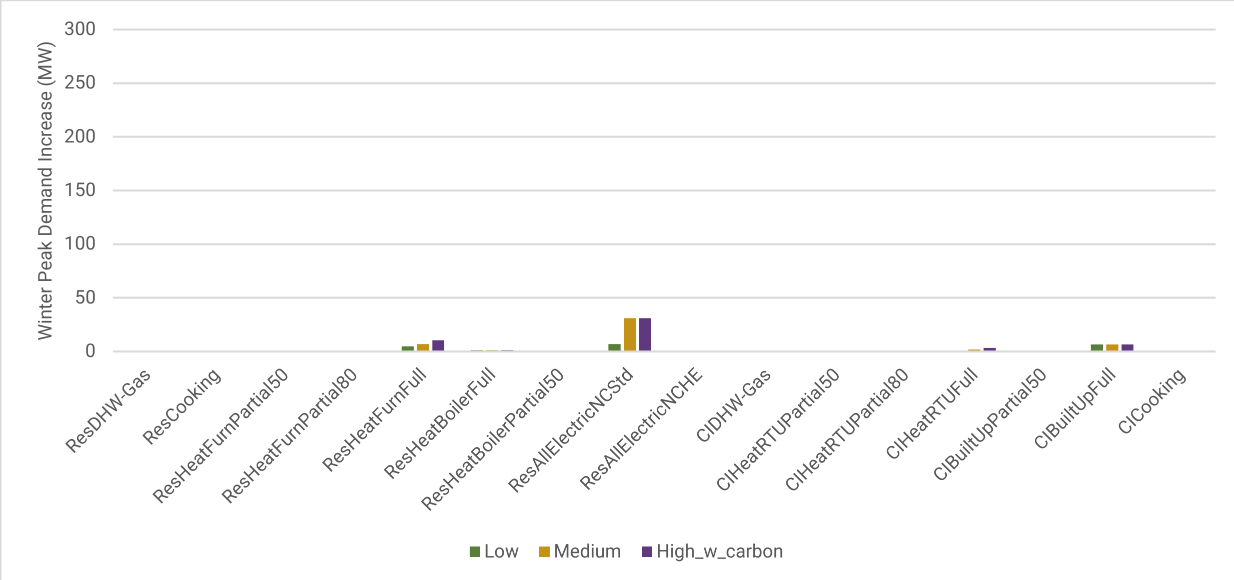
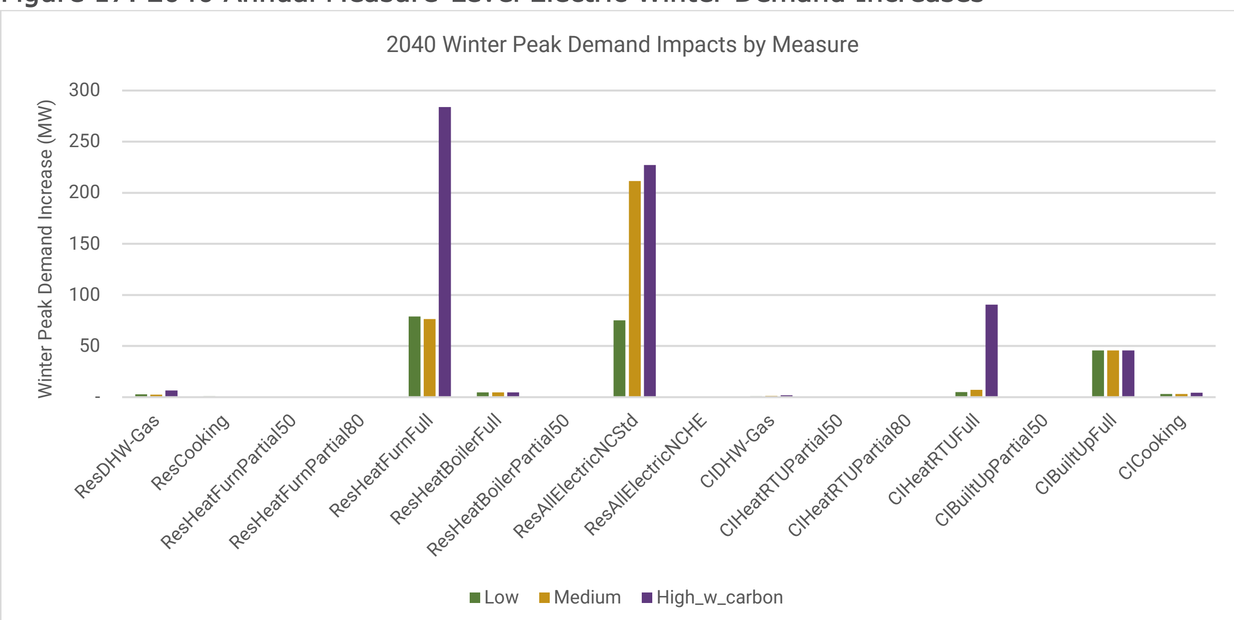


Figure 17. 2040 Annual Measure-Level Electric Winter Demand Increases



6. Forecast Overall Building Electrification Impacts

For each forecasted scenario, Apex estimated the following grid impacts, by adding up the measure-level impacts for each scenario:

- Annual electricity and fuel impacts
- Summer and winter peak impacts
- Monthly electricity and peak impacts

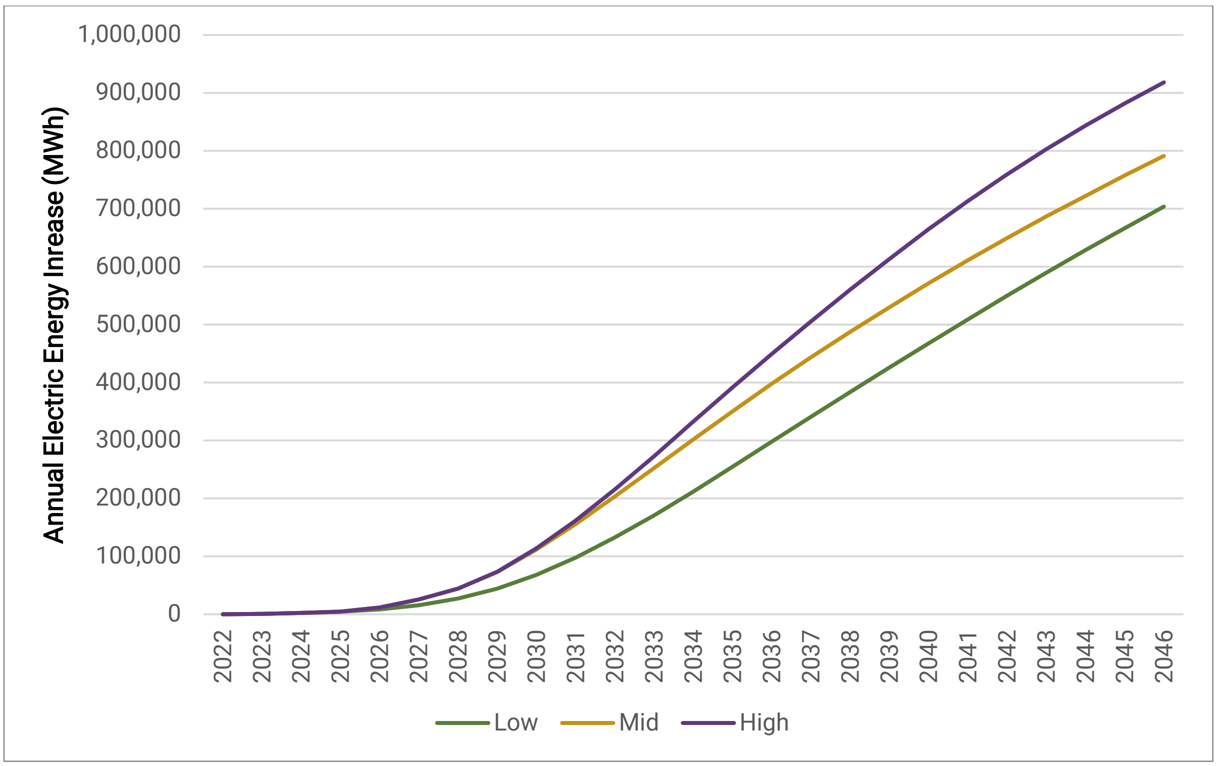
- Extreme temperature peak impacts (winter)

6.1 Energy Forecast

Key Finding: Building electrification will have substantial energy impacts but only after 2030.

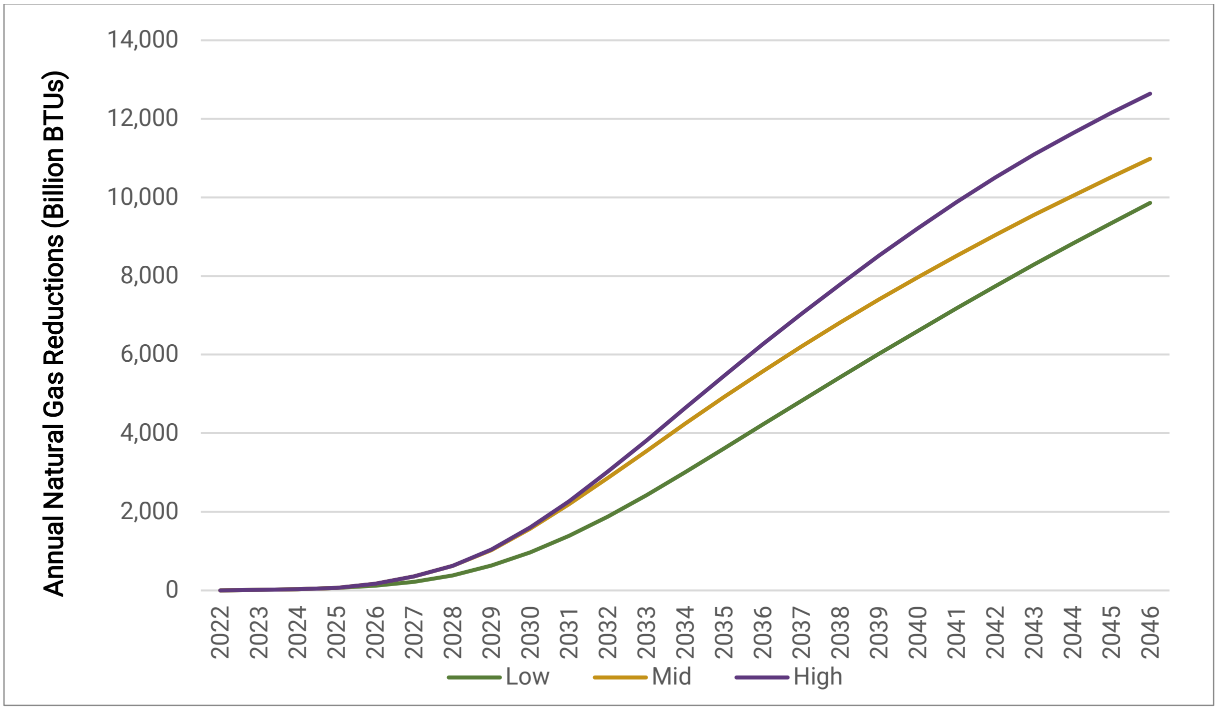
The annual electric energy increase resulting from building electrification shows only minor gains through 2030 (Figure 18). Yet, building electrification load accelerates after 2030, going from 2% (of base load) in 2030 to about 12% in 2040 (per the low scenario).

Figure 18. Building Electrification Annual Electric Energy Forecast Increase



The annual natural gas energy reductions resulting from building electrification mirror the electric energy increases (Figure 19).

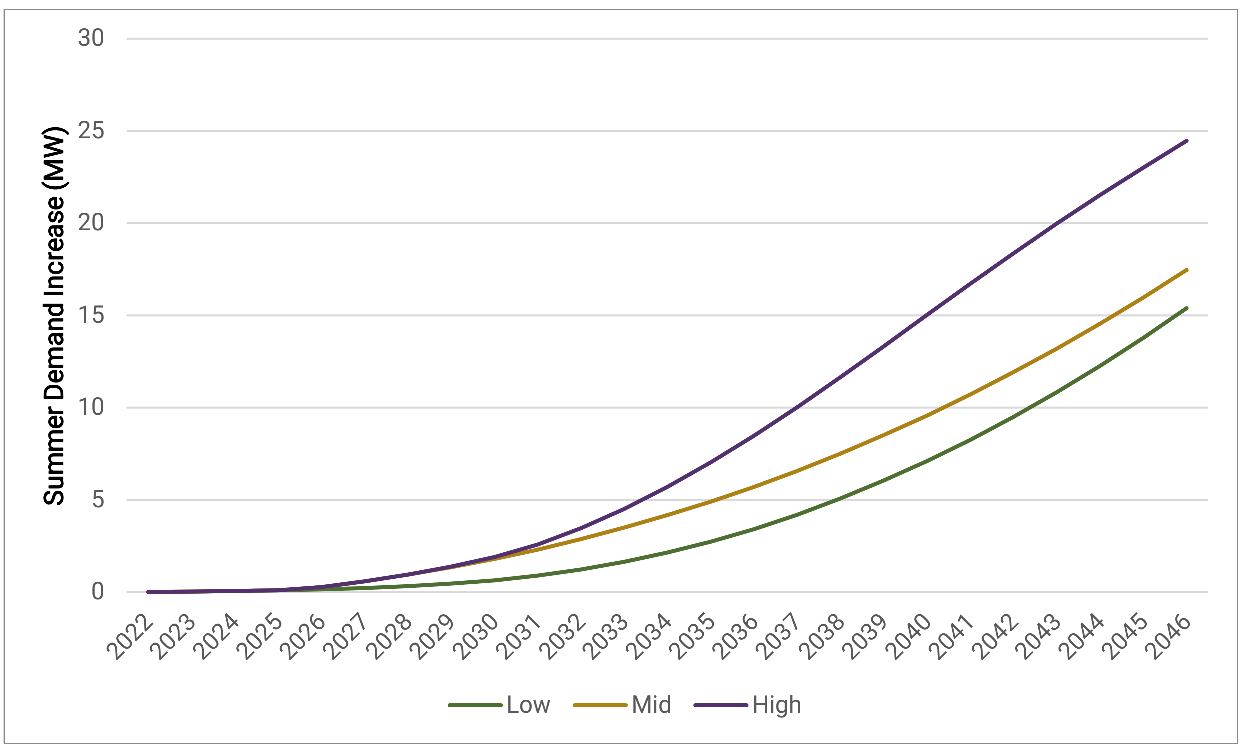
Figure 19. Building Electrification Annual Natural Gas Forecast Reductions



6.2 Summer Peak Demand Forecast

Figure 20 below shows the summer peak demand from building electrification.

Figure 20. Building Electrification Annual Summer Peak Demand Forecast Increase

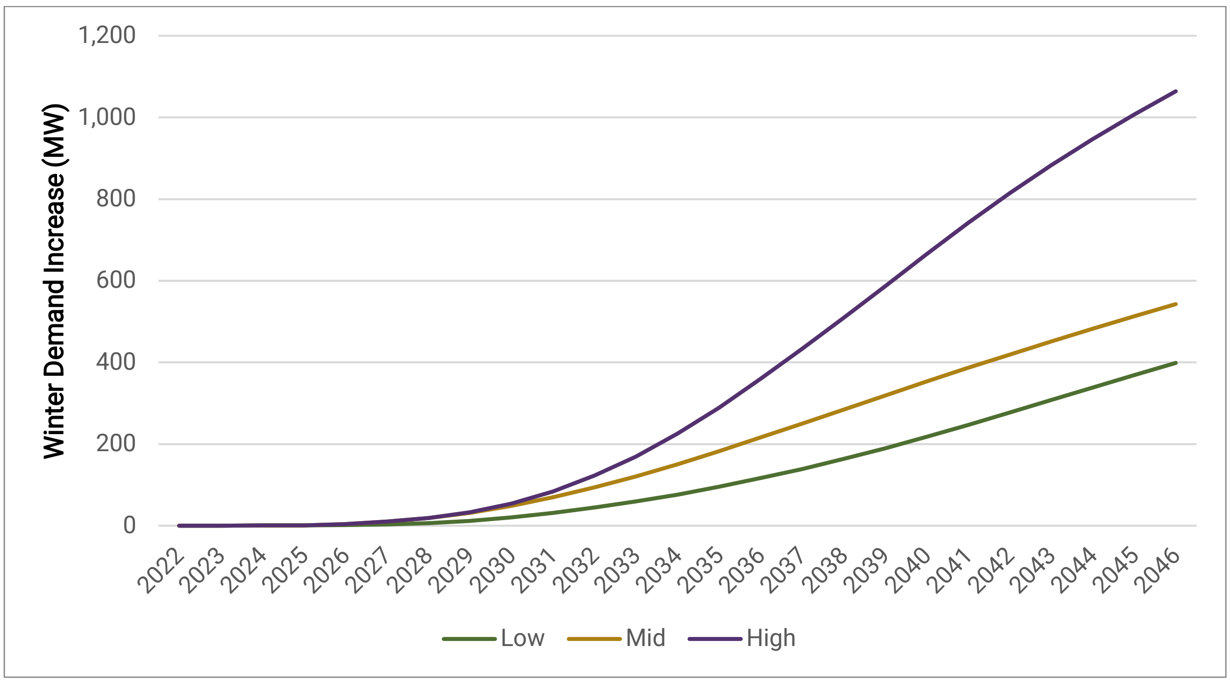


Key Finding: Building electrification will have minimal summer peak demand impacts. This is because heat pump water heaters only add 0.1 kW per home, electric cooking adds even less, and the forecast had very few homes that incidentally acquired central cooling due to electrification of heating. Most homes adding heat pump heating are projected to already have central cooling at the time of the heat pump installation.

6.3 Winter Peak Demand Forecast

The winter peak demand forecast shown in Figure 21, similar to energy, shows only marginal increases through 2030, but unlike summer peak demand, winter peak increases rapidly in the 2030s, primarily driven by all-electric newly constructed homes.

Figure 21. Building Electrification Annual Winter Peak Demand Forecast Increases



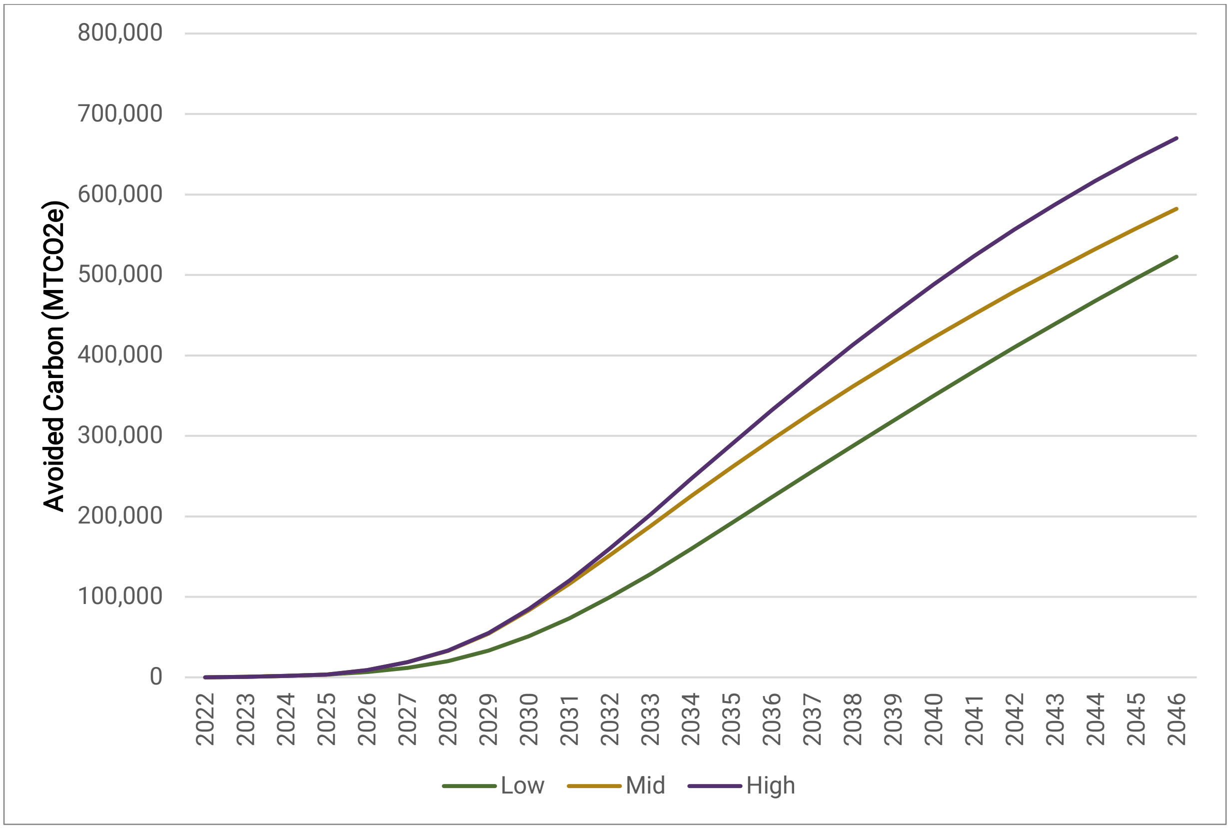
Key Finding: Building electrification may cause Platte River system to become winter peaking sometime after 2035.

Key Finding: The earlier adoption of all-electric new building code would cause winter peaking roughly 5-10 years later. Depending on how much electrification has already taken place before the code goes into effect, all-electric new building codes cause Platte River to rapidly become winter peaking.

6.4 Carbon Reduction Forecast

Key Finding: Building electrification will result in substantial carbon reductions. Annual carbon reductions associated with the electrification equipment forecast can be reflected with the concurrent reductions in fossil fuel consumption. Apex estimated the annual carbon reductions associated with declining fossil fuel consumption in buildings, independent of the carbon intensity of electricity, which clouds the results. This is equivalent to estimating carbon impacts for electrification in a carbon-free grid scenario, which is approximately what is expected after 2030. Results of the carbon reduction forecast are shown across the three scenarios in Figure 22. It is important to clarify that the carbon reductions do not reflect any reductions in carbon intensity to Platte River's generation portfolio.

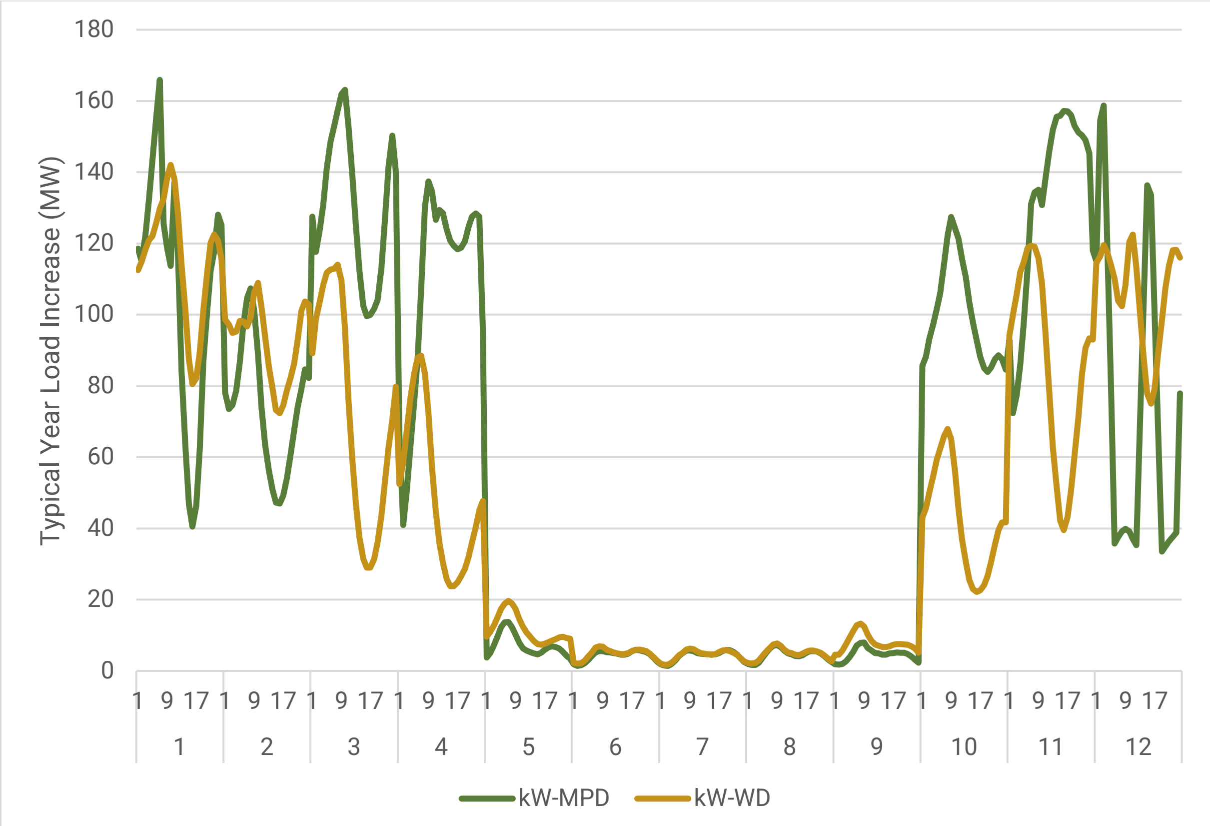
Figure 22. Building Electrification Annual Non-Electric Carbon Reduction Forecast



6.5 Monthly and Hourly Load Shapes

Apex applied the hourly load shapes by measure to the energy impacts, then summed across measures to get the total hourly impacts by scenario and year. For example, the results for the 2040 low scenario are shown in Figure 23. The gold kW-WD line shows the typical weekday hourly shape for 24 hours for each of the 12 months, while the green line shows the typical peak day shape for each month. Somewhat counterintuitively, the green peak day shape is lower than the golden weekday shape during the middle of winter because the partial displacement heat pumps will more likely be running on typical days, while they are likely to be off during colder winter peak periods when their gas backup systems run instead. Additional load shapes have been separately provided for inclusion in planning models.

Figure 23. Forecasted 2040 “Low” Scenario Building Electrification Monthly and Hourly Load



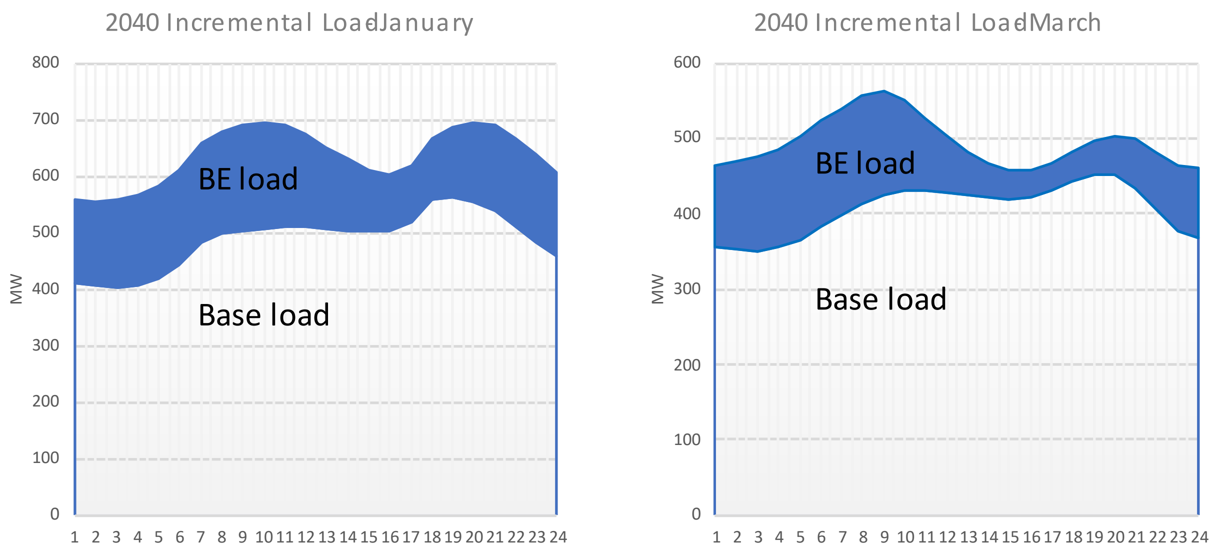
Key Finding: Building electrification is a winter-focused load.

Key Finding: Building electrification impacts occur more in the morning.

Monthly peak day impacts for a building electrification load made up primarily of partial displacement heating equipment, as reflected in the 2040 low scenario above, have a built-in winter demand reduction. During cold temperatures, below 20 degrees, it’s assumed that most heat pumps have switched over to using a gas furnace, which is reflected in the monthly peak days having lower hourly loads than the typical weekday in December/January/February.

When these loads are added to the existing load forecast for 2040, as shown in Figure 24 below, we can see the overall load being substantially increased, especially in January.

Figure 24. Building Electrification 2040 Incremental Hourly Load in January and March



Key Finding: By 2040, electrified buildings will contribute to transforming Platte Rivers system to being dual peaking, while also shifting winter daily peak from evening to early morning.

6.6 Load Flexibility and Demand Response

Conventional demand response opportunities for building electrification are limited. The only building electrification measure with substantive demand response potential is the heat pump water heater. However, a heat pump water heater has lower demand than a conventional water heater, with lower peak demand impact. The diversified, coincident peak demand of a heat pump water heater is only 0.1 kW during the current evening peak. During a future winter morning peak, the coincident peak demand of the heat pump water heater rises to 0.2 kW. Explain Table 10 pls.

Table 10. Building Electrification Conventional Demand Response Potential by Scenario

Year	Low Scenario Tech Potential (kW)	Medium Scenario Tech Potential (kW)	High Scenario Tech Potential (kW)
2025	54	78	78
2030	332	751	861
2035	1,067	2,255	3,649
2040	2,851	4,470	8,423
2045	6,198	7,641	12,867

While heating equipment demand response programs do exist, customers generally do not like them and in Northern Colorado climate, this is not feasible during extreme cold weather, where the home may take days to recover from a significant setback.

Building electrification measures DO offer additional load flexibility that will be useful for following the output of intermittent renewables. Connected water heaters and connected thermostats serving heat pumps both offer significant load flexibility in a couple of different ways.

Daily load shifting, soaking up excess renewable generation. A home with a heat pump can theoretically be pre-heated during hours with high solar or wind output. Two degrees of preheating provides approximately 3-10 kWh of load shifting, depending on the home characteristics, the outdoor temperature, and the efficiency of the heat pump. There may be situations where the heat pump is already running and load shifting is not possible, but those days do not tend to have excess renewable generation – the load is already high. Connected water heaters are also being used to do the same thing but may require a mixing valve be installed.[20]

Fast ramping to match wind/solar output. Building electrification loads can be triggered to turn on or off with a response time of less than 1 minute. It's generally easier to use this capability to soak up excess generation than it is to reduce consumption to make up for loss of generation, because there are more hours available with relatively low usage than relatively high usage. Depending on the heating and hot water usage at the time of the event, each home can add or subtract between 0.5 and 5 kW over a short duration. To date, while many experts have pointed to this capability, utilities have yet to deploy it at scale.

6.7 Load and Temperature Relationship

Apex calculated the temperature responsiveness of the overall building electrification load in 2040 by first calculating the 8760 hourly loads for this scenario and time and then fitting a regression equation to this data. The final regression equation uses heating degree hours, a population load factor to deal with varying switchover temperatures, and a heat build up term to deal with load varying as a function of recent weather, not just current absolute temperature:

Normalized hourly consumption = A + B * hdh.20 + C*hdh.55*pop.load.factor + D*pop.load.factor*NHBU

With coefficient values:

Coefficient	Value
A (constant)	-0.0000001710
B (hdh.20)	0.0000134882
C (hdh.55*pop.load factor)	0.0000109605
D (NHBU*pop.load factor)	0.0000000879

Where:

Hdh.20 = heating degree hours base 20

[20] This has been piloted in a few places, e.g. Georgia: PowerPoint Presentation (peakload.org)

Hdh.55 = heating degree hours base 55

pop.load factor = 0.00001348815 * cooling degree hours base 20

NHBU = normalized heat build up, defined as

$$NHBU = \sum_{t=1}^{72} 0.96^t * HDH\_65$$

Where t runs from 1 to 72 hours before the present time and HDD_65 is heating degrees hours base 65.

The end result of the modeling shows that there's a complicated relationship between temperature and consumption above 20 degrees, but below 20 degrees, one could use a polynomial relationship instead. However, this relationship is limited by a lack of data on actual real world heat pump behavior.

6.8 Distribution System Impacts

Apex staff developed an Excel-based distribution impacts tool, provided as a separate deliverable to Platte River. The goals of this tool were to allow utility staff to examine different scenarios of building electrification using outputs from the study on distribution equipment serving predominantly residential loads. The tool uses the diversity of the loads across houses, the overall saturation of equipment, existing loading, and rating of distribution equipment to estimate the fraction of pieces of like equipment that would exceed design thresholds in that scenario.

7. Conclusions, Recommendations, and Next Steps

Some key findings have been provided throughout the results sections of the report. The most impactful conclusions and recommendations are provided below.

7.1 Conclusions

Conclusion 1: Electrifying space heating with heat pumps is the highest impact building electrification technology; **residential heat pumps are expected to have the highest incremental load**.

Conclusion 2: Only minor impacts on overall electricity consumption and peak demands are expected through 2030. Starting in 2030s, building electrification impacts increase rapidly.

Conclusion 3: Heating electrification creates opportunities and costs.

- **Partial electrification of heating improves load factor.** Building electrification is a winter-focused load with larger impacts overnight and in the morning. Partial electrification heat pumps rely on gas backup furnaces during extreme winter peak weathers, making them an ideal measure for load factor improvement.

- **Full electrification of heating may cause Platte River to become winter peaking sometime after 2035.** Full electrification heat pumps use backup electric resistance heat, causing additional winter peak loads of 10 kW per home. Even cold climate heat pumps require a backup during extreme cold weather.
- **Full electrification of heating causes significant cost and reliability impacts.** A new winter peak will be difficult to meet with demand response or storage, because it can have a long duration with only small dips in load over the course of multiple days.

Conclusion 4: Policies requiring all-electric new homes and/or businesses could push impacts sooner – **winter peaking will occur within ~5-10 years of requiring all-electric new homes**.

Conclusion 5: Building electrification provides only small opportunities for traditional demand response, but **big opportunities for load flexibility to help with ramping of intermittent renewable resources**.

Conclusion 6: Without substantive changes to the market or policy changes, utility programs will be required to drive high adoption of electrification technologies. This will allow utilities to play an active role in the adoption of building electrification and strengthen their supply network in an orderly fashion for eventual full electrification.

7.2 Recommendations

Based on the study results showing BBE load growing slowly in the next few years and accelerating thereafter, we offer the following recommendations:

Recommendation 1: Incorporate building electrification load in the future load forecasts.

Recommendation 2: Be prepared to advise policy makers on large grid impacts of BBE. An orderly adoption will allow a reliable and lower cost transition????

Recommendation 3: Revisit building electrification forecast during each IRP to incorporate adoption rate of heat pumps, changes in city codes and policies.

7.3 Future Work

As building electrification support efforts gain traction here and across the country, more information about building electrification applications and adoption rates will become available.

Platte River should consider expanding their efforts on anticipating the impacts from beneficial building electrification by conducting the following research to improve on the uncertainty:

- Platte River should consider revisiting this forecast consistent with future IRP planning efforts or if major developments occur via market forces or member community actions.
- Additional study of commercial heat pump and heat pump water heater adoption rates from elsewhere
- Revised adoption rates of full electrification heat pumps vs partial electrification heat pumps pulled from elsewhere and local data
- Revised all-electric home adoption rates based on local data and clearer policy direction
- Additional, more granular analysis of impacts of combined envelope efficiency measures with electrification measures
- Analysis of combined electric vehicle and building electric end use interactive impacts on distribution equipment

Appendix A: Spreadsheet Data Appendices

Accompanying this report, we are providing detailed data outlining assumptions and hourly forecasts not covered in the body of the report.

The spreadsheet appendices consist of:

1. Forecast results inputs and outputs: "Forecast Model Results.xlsx" contains the following sheets consisting of almost all forecast inputs and outputs.

Sheet Name	Contents
Documentation	List of sheets and their contents.
Res Sector Charts	Results plots for the residential sector.
Com Sector Charts	Results plots for the commercial sector.
Combined Results	Commercial and Residential Combined Results by measure for three key scenarios.
Measure Tables and Charts	Measure-level results plots.
Pivot_Res_Segment	Pivot table of results by stock segment (includes market penetration, unit sales, and stock size by stock segment).
Pivot_Res_Measure	Pivot table of results by measure (this has pivot table of full residential results).
Pivot_Com_Measure	Pivot table of results by measure (this has pivot table of full commercial results).
Res Segment Forecasts	Quantities by stock segment (includes market penetration, unit sales, and stock size by stock segment).
Res Measure Forecasts	Results by measure, including each of the impacts.
Com Segment Forecasts	Quantities by stock segment (includes market penetration, unit sales, and stock size by stock segment).
Com Measure Forecasts	Results by measure, including each of the impacts.
Staging 4 CE Input	Measure-level unit impacts.

Load shape export	Measure-level load shapes showing monthly and hourly results of form kWh_time = Value * Annual Energy Impacts
Envelope Improvement	Vector of assumed multipliers by year for envelope improvement scenario.

2. Overall load shape outputs: "BE EE Stock Hourly Forecast Results_2022-01-18.xlsx"
    a. 'Index' contains indices for selecting shapes.
    b. 'No Sector' contains load shapes by scenario, year, month, and hour for average weekday, average weekend day, monthly peak day. Shapes include raw total MW, smoothed total MW, Smoothed Energy Normed (Smoothed MW/annual MWh), and Smoothed Peak Normed (MW/annual max MW)
    c. 'Pivot Chart' contains a pivot chart and a load shape comparison graphic allowing people to choose load shapes for comparison on a plot.
    d. 'Total_MWh' contains the annual MWh and annual max MW for each scenario by year for normalizing purposes.
2. Distribution Equipment Impacts Tool: Distribution Equipment Impacts.xlsx