The Economics of All-Electric New Construction in Utah

An evaluation of residential new construction costs and energy bill impacts for single-family and low-rise multi-family properties across the state

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Energy+Environmental Economics

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Table of Contents

List of Figures

List of Tables

Acronym Definitions

Acronym	Definition
AC	Air Conditioning
AFUE	Annual Fuel Utilization Efficiency
ASHP	Air Source Heat Pump
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ccASHP	Cold Climate Air Source Heat Pump
COP	Coefficient of Performance
CZ	Climate Zone
DOE	U.S. Department of Energy
EF	Energy Factor
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
EV	Electric Vehicle
ER	Electric Resistance
GHG	Greenhouse Gas
HFCs	Hydrofluorocarbons
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
ICCT	International Council on Clean Transportation
IECC	International Energy Conservation Code
kWh	Kilowatt-hour
MMBtu	Million British Thermal Units
NEEP	Northeast Energy Efficiency Partnership
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPV	Net Present Value
PM2.5	Fine Particulate Matter
PNNL	Pacific Northwest National Laboratory
RECS	Residential Energy Consumption Survey
SEER	Seasonal Energy Efficiency Ratio
SWEEP	Southwest Energy Efficiency Project
TMY3	Typical Meteorological Year weather data format
UBCC	Uniform Building Code Commission
UCE	Utah Clean Energy
UEF	Uniform Energy Factor

Executive Summary

This report features an analysis of the energy use and financial outcomes of two different approaches to constructing new residential properties in Utah. Specifically, this report evaluates installed cost impacts, energy use, and resulting energy bill costs for:

- Newly constructed all-electric single-family homes and low-rise multi-family buildings built with equipment and appliances that only use electricity; and,
- Newly constructed "mixed fuel" single-family homes and low-rise multi-family buildings built with equipment and appliances that use both electricity and natural gas (shortened to "gas" in remainder of report).

Interest in all-electric properties has been increasing throughout Utah due to the associated air quality, public health, and environmental benefits from this type of construction. These benefits are increasingly accessible as all-electric technologies like air-source heat pumps (ASHPs) and heat pump water heaters (HPWHs) continue to improve in energy performance, particularly for colder climates, thus reducing the operating costs of these technologies for basic household energy needs like space heating and water heating.

This analysis relies on pre-existing datasets and modelling software from the U.S. Department of Energy (DOE) to estimate the installation costs, operational energy use, and ongoing utility bills for newly constructed all-electric residential properties and "mixed fuel" properties. The analysis was completed for all three common climate zones in Utah, as defined by the International Energy Conservation Code (IECC). Key takeaways from this report include:

- **All-electric homes and multi-family properties can be built at lower cost in Utah compared to mixed-fuel properties,** which can help improve housing affordability across the state by reducing housing construction costs;

- When including energy efficient technologies like electric heat pumps, **all-electric homes can result in energy bill savings for customers in all major climate zones in Utah**;

- Equipment selection is important for maximizing energy bill savings and lifecycle benefits for residential buildings. **Financial outcomes are optimized through use of high-performing HVAC, water heating, and other equipment;**

- In addition to lower construction costs and enhanced energy bill affordability, **all-electric properties can deliver air quality benefits and carbon reductions** while also taking advantage of ongoing technology improvements.

These results may seem counter to certain prevailing attitudes about gas appliance use in Utah, including the relative affordability of efficient all-electric appliances. However, the findings are in line with other research across the country that has documented both construction cost savings and ongoing energy cost savings associated with all-electric homes.

Audience Note: this report was written for use by various audiences in Utah, including building professionals, housing developers, policymakers, government agencies, non-profit organizations, and members of the public who are interested in the potential of all-electric new construction in the state. Details on assumptions, data sources, and modelling approach are included within the report and its appendices.

1 Introduction

Consumer Economics of All-Electric New Construction

This report provides objective data on the consumer economics of all-electric new construction in Utah. The data presented in this report will guide members of the public, including building professionals, housing developers, and policymakers to make well-informed decisions on building design and building policy. This report does not put a monetary value on the environmental and social benefits of all-electric new construction and only quantifies the costs experienced by a homebuilder, homeowner, or property occupant such as a renter.

Consumer economics is split into two categories in this report:

- **Installed cost**: The cost to purchase and install given building systems, such as HVAC or water heating, during new construction. This is a function of equipment specifications and supporting infrastructure within a residential building.
- **Energy bills:** The ongoing costs of operating a building through electricity and gas bills. This is a function of equipment efficiency, building envelope characteristics, and retail energy rates. Occupant behavior is another factor impacting energy use, but only a single baseline set of assumptions was used in this analysis.

Together, these cost categories can guide decision-making in different applications. Some housing developers may prioritize larger upfront investments with paybacks from reduced energy bills over the building lifecycle. Other housing developers may be more sensitive to first costs and seek to minimize upfront installed costs. Policymakers and non-profit organizations may seek building designs with lower energy bills to provide more financial security for residents in affordable housing developments.

Finding economically beneficial opportunities for all-electric buildings in Utah will help realize other associated benefits such as reducing air pollution to improve personal and public health and reducing carbon emissions to help mitigate climate change. The remainder of this section explains certain public health and environmental benefits of all-electric new construction, first focusing on local air quality and then the reduction of carbon emissions. While the air quality and climate benefits of all-electric new construction were not modeled in this analysis, the studies and reports referenced below make it clear that all-electric properties will benefit local air quality and reduce carbon emissions over time.

All-Electric Homes Improve Indoor and Outdoor Air Quality

Utah residents consistently rank poor air quality among their highest issues of concern. A representative survey of statewide residents commissioned by Envision Utah found that *air quality was perceived as the third highest rated issue* in terms of "importance to Utah's future," ranking it ahead of other issues such as healthcare, housing, and economic development.[1] These concerns are informed by direct experience in northern Utah where the Salt Lake City-Provo area ranks among *the worst 5% of U.S. metropolitan regions in terms of number of poor ozone days annually and 24-hour particle pollution* according to the 2020 "State of the Air" study by the American Lung Association.[2]

All-electric properties offer a solution for improving both indoor and outdoor air quality by eliminating onsite fossil fuel combustion from gas, propane, and fuel oil appliances. Recent research from groups such as RMI has documented the indoor air quality consequences of combusting gas in stoves and cooktops.[3] Additionally, research by the U.S. Environmental Protection Agency (EPA) states that *homes with gas cooking appliances experience nitrogen dioxide (NO_2) pollution concentrations that are 50% to over 400% higher* than in homes with electric cooking appliances. This same EPA study also noted that the link between gas cooking appliances and NO_2 pollution remains strong even when adjusting for several factors within the home.[4]

In terms of outdoor air pollution, RMI research has indicated that "*because gas appliances lack effective emission controls, they emit more than twice as much NOx as gas power plants [in the U.S.]*, despite consuming less gas overall".[5] Drawing off peer-reviewed research from the Harvard T. Chan School of Public Health, RMI published a state-by-state summary that reflects annual public health impacts of $361 million per year in Utah from burning fuels such as gas, oil, biomass, and wood in buildings.[6]

In addition to appliance electrification, the installation of electric vehicle (EV) charging infrastructure in newly constructed buildings represents an additional opportunity to reduce local pollution and improve public health in Utah. Along with reducing carbon emissions, EVs can deliver sizable benefits for outdoor air quality. Research published by the Southwest Energy Efficiency Project (SWEEP) and Utah Clean Energy (UCE) highlighted major reductions in contributions to air pollution along the Wasatch Front in Utah for an all-electric vehicle compared to a new gasoline vehicle. The study evaluated both tailpipe emissions and upstream impacts of generating electricity at power plants and found that *along the Wasatch Front, EVs reduce VOCs by 99%, reduce NOx emissions by 90%, and reduce PM2.5 emissions by 81% relative to a gasoline vehicle*.[7] As a complementary solution to all-electric buildings, the transition to EVs will be accelerated if more homes and buildings install EV charging infrastructure during construction.

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[1] "2014 Values Study Results," Envision Utah, 2014, https://yourutahyourfuture.org/images/final_values_study_report.pdf
[2] "State of the Air," American Lung Association, 2020, https://www.lung.org/research/sota/city-rankings/msas/salt-lake-city-provo-orem-ut#pm24
[3] "Gas Stoves: Health and Air Quality Impacts and Solutions," RMI, 2020a, https://rmi.org/insight/gas-stoves-pollution-health/
[4] "Integrated Science Assessment for Oxides of Nitrogen – Health Criteria," U.S. EPA, 2008, https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=194645
[5] "Factsheet: Why EPA Must Address Appliance Pollution," RMI, 2021a, https://rmi.org/wp-content/uploads/2021/04/rmi_factsheet_appliance_pollution.pdf
[6] "What is the Health Impact of Buildings in Your State?," RMI, 2021b, https://rmi.org/health-air-quality-impacts-of-buildings-emissions
[7] "The Potential for Electric Vehicles to Reduce Vehicle Emissions and Provide Economic Benefits in the Wasatch Front," Southwest Energy Efficiency Project (SWEEP) and Utah Clean Energy (UCE), 2017, https://www.swenergy.org/data/sites/1/media/documents/publications/documents/2017_EV_Emissions_Update_Wasatch_Front_Jan-2017.pdf

All-Electric Homes Reduce Carbon Emissions

In addition to improving local air quality, all-electric buildings have the potential to reduce carbon emissions, particularly as the electric grid becomes cleaner and is supplied by an increasing amount of renewable energy. Burning gas in buildings creates a sizable amount of carbon emissions across the U.S. and in Utah. *In Salt Lake City, for example, an estimated 26% of citywide carbon emissions were attributed to onsite natural gas combustion in buildings and facilities* in 2015.[8]

Research published in Colorado[9], New York[10], and California[11], as well as nationally[12], identify building electrification and corresponding electricity sector decarbonization as key pillars to decarbonizing the building sector, and the economy more broadly. The carbon benefits of electrification in Utah are forecasted to increase over time as *the parent company of Utah's largest electricity provider, Rocky Mountain Power, has published a plan that would reduce greenhouse gas emissions from the electric grid by 74% by 2030* relative to 2005 baseline. This is part of an even longer-term transition to renewable energy by the utility's parent company, PacifiCorp, which envisions carbon emissions from the grid being reduced 98% by 2050.[13]

Alongside the carbon benefits of electric heat pumps, installing EV charging infrastructure to support the increased use of EVs will also help reduce emissions over product lifecycles. Among numerous studies on this topic, the International Council on Clean Transportation (ICCT) found that "*[GHG] emissions over the lifetime of average medium-size BEVs [Battery Electric Vehicles] registered today are already lower than comparable gasoline cars by 60%–68% in the United States*".[14] Similar to emissions trends anticipated with electric heat pumps, the ICCT research notes that the carbon benefits of EVs will increase substantially over time as the electric grid continues to become cleaner.

One additional consideration includes greenhouse gas emissions from refrigerants associated with certain electric heat pump technology. Similar to central air conditioners (ACs), air source heat pumps (ASHPs) require refrigerants to move heat in order to control interior space temperature and water temperature. However, as research from the University of California-Davis has indicated, *lifecycle carbon emissions from*

[8] "Climate Positive 2040," Salt Lake City Sustainability Department, 2017, http://www.slcdocs.com/slcgreen/CP0320.pdf

[9] "Colorado Greenhouse Gas Reduction Roadmap," Colorado Energy Office, Energy and Environmental Economics, Inc, 2021, https://energyoffice.colorado.gov/climate-energy/ghg-pollution-reduction-roadmap

[10] "Pathways to Deep Decarbonization in New York – Final Report," Energy and Environmental Economics, Inc, NYSERDA, 2020, https://climate.ny.gov/Climate-Resources

[11] "Deep Decarbonization in a High Renewables Future," Energy and Environmental Economics, Inc, 2018, https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf

[12] "Net-Zero America: Potential Pathways, Infrastructure, and Impacts", Larson et al, 2021, https://netzeroamerica.princeton.edu

[13] "PacifiCorp's updated plan accelerates a bold energy future with low-cost, reliable, sustainable power for its customers," Rocky Mountain Power, 2021a, https://www.rockymountainpower.net/about/newsroom/news-releases/2021-integrated-resource-plan.html

[14] "A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars," The International Council on Clean Transportation (ICCT), 2021, https://theicct.org/publications/global-LCA-passenger-cars-jul2021

efficient heat pump technology are lower relative to a gas furnace in residential applications in the U.S., even when accounting for all factors including refrigerant use.[15] Refrigerant concerns are expected to decline over time due to recent federal legislation that requires new refrigerant rules from EPA, including a "phase down [in] the production and consumption of HFCs [hydrofluorocarbons] by 85% below baseline levels within the next 15 years."[16]

The above benefits combine to make all-electric new construction an attractive option for both individual households and the broader energy systems that can be improved by smart electrification. *Utahns can immediately benefit from newly constructed all-electric homes*, particularly with the continued deployment of renewable energy and smart appliances that reduce pollution, help manage electric loads, and enhance system-wide affordability. Given the non-monetized benefits of building electrification, it is important to study the direct economic impacts on consumers to determine if there is an incremental cost to realizing these benefits. The following sections in this report explore this question.

2 Methodology

2.1 Building Prototypes

This report analyzes two residential building types in Utah—single-family homes and low-rise multi-family buildings—and reflects results across all three major climate zones in the state. Building assumptions and location characteristics were drawn from existing federal government datasets typically used to perform energy code modelling for Utah and other states.

Building energy consumption for each building prototype was calculated with data from Pacific Northwest National Laboratory's (PNNL) database of Residential Prototype Building Models.[17] To reflect Utah's unique amendments to the 2015 IECC new construction building standards, prototypes were provided by staff at PNNL that directly match these specifications; see PNNL report on cost effectiveness of the Utah building code for further details on included specifications.[18] Figure 1 below provides a summary of the building prototypes used in the analysis for this report.

[15] "Greenhouse gas emission forecasts for electrification of space heating in residential homes in the United States," U.C. Davis Western Cooling Efficiency Center, 2021, https://ucdavis.app.box.com/s/dqja4itdlh1wwicyjh6wag5yswwf97tc

[16] "Fact Sheet: Biden Administration Combats Super-Pollutants and Bolsters Domestic Manufacturing with New Programs and Historic Commitments," The White House, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/23/fact-sheet-biden-administration-combats-super-pollutants-and-bolsters-domestic-manufacturing-with-new-programs-and-historic-commitments/

[17] "Prototype Building Models," Pacific Northwest National Laboratory (PNNL), Accessed 2021, https://www.energycodes.gov/prototype-building-models#Residential

[18] "Cost-Effectiveness Analysis of the Residential Provisions of the 2015 IECC for Utah," Pacific Northwest National Laboratory (PNNL), 2016, https://www.energycodes.gov/sites/default/files/2019-09/UtahResidentialCostEffectiveness_2015.pdf

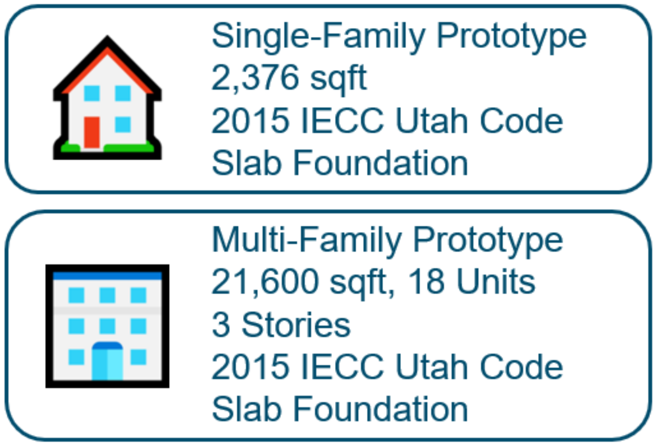
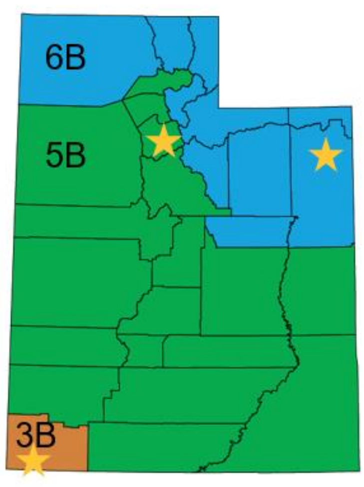


Figure 1. Summary of prototype buildings used in this analysis

Building simulations based on these prototype models were then performed in the U.S. Department of Energy's (DOE) EnergyPlus modelling software with Utah-specific weather considerations. Utah's geography spans three climate zones as designated by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for its model standards referenced in energy codes such as the IECC. The three climate zones and specific weather stations utilized are Climate Zone 3B (St. George Regional Airport), Climate Zone 5B (Salt Lake City International Airport), and Climate Zone 6B (Vernal Regional Airport) (see Figure 2). These sites were selected based on weather data availability and records to conform with TMY3 (Typical Meteorological Year) standards and modelling software needs.



	TMY3 Weather Station
Climate Zone 3B	St George Regional Airport *ID: 724754*
Climate Zone 5B	Salt Lake City Int'l Airport *ID: 725720*
Climate Zone 6B	Vernal Regional Airport *ID: 725705*

Figure 2. Map of Utah's ASHRAE climate zones and location of weather stations[19]

[19] "Utah Climate Zone Map," Building Codes Assistance Project, Accessed 2021, http://bcapcodes.org/wp-content/uploads/2012/01/cz-map_utah.png

2.1.1 Adjustments to DOE Prototype Building Characteristics, HVAC Modeling and Sizing

This analysis utilizes building envelope performance and most end-use energy loads directly from the standard EnergyPlus model runs for the building types and Utah climate zones listed above. Some additional adjustments were made to these models to better reflect Utah's building stock and new construction technology options. Plug load energy consumption was decreased by 25% and fan energy use was decreased by 50% to better align with empirical end use consumption reflected in the Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) database.[20]

To facilitate modeling of additional heat pump space heating technology options, space heating service demand was extracted from the EnergyPlus models and post-processed to reflect specified heat pump performance curves and custom sizing. Non-cold climate heat pumps were sized to cover all space heating loads in a building at an outside temperature of 20 degrees Fahrenheit, and electric resistance heating was assumed to provide supplementary backup heat at temperatures below this threshold. Cold climate heat pumps were sized to provide the full building heating load, with no supplementary backup heat.

2.2 Technology Packages

This analysis evaluates examples of newly constructed all-electric residential building types and compares these to mixed fuel alternatives in which both electric and gas appliances are installed in the building. Scenarios with both electricity and gas are described as "mixed fuel" throughout this report.

Four technology packages were included in the analysis and are summarized in Figure 3 below. The specified efficiencies and equipment selections are the same for both single-family and multi-family building prototypes, although it is noted that equipment sizing and installation costs vary by prototype. The four technology packages are:

+ **Mixed Fuel Baseline**: Represents a baseline case with both electricity and gas service and specifies equipment that meets federal minimum efficiency standards.
+ **Ducted All-Electric:** Includes all-electric equipment including a heat pump water heater and ducted air-source heat pump (ASHP). The ASHP provides both space heating and cooling. This package is only included for single-family homes due to the prevalence of ducted HVAC currently in these building types.
+ **Ductless All-Electric:** Includes all-electric equipment including a heat pump water heater and a ductless ASHP (a.k.a. "mini-split"). The ASHP provides both space heating and cooling.
+ **Cold Climate (CC) Ductless All-Electric:** Includes all-electric equipment including a heat pump water heater and a ductless cold climate ASHP. The ASHP provides both space heating and

[20] "Residential Energy Consumption Survey (RECS)," U.S. Energy Information Administration (EIA), 2015, https://www.eia.gov/consumption/residential/

cooling. This package is only included as an option in colder climate zones 5B and 6B in Utah as an alternative to basic ASHP equipment.

All-electric prototypes in climate zone 3B, as well as the Cold Climate Ductless All-Electric prototypes in Climate zones 5B and 6B, assume no supplemental heat as the heat pumps are sized to meet peak heating loads. The all-electric prototypes in climate zones 5B and 6B with non-cold climate heat pumps assume electric resistance backup heat. For ducted ASHPs, the backup heating system is assumed to be resistance coils installed within the system. For ductless ASHPS in colder climates, supplemental heat is sometimes provided by electric resistance baseboard heating when non-cold climate heat pumps are installed. However, this pathway increases costs and was not included in this analysis. Alternatively, the modeling reflected in this report for the two colder Utah climate zones (5B and 6B) includes cold climate ductless heat pump scenarios which have improved upfront and operating cost characteristics.

Heat pump technology continues to improve and builders or homeowners may also choose to install more efficient heat pump equipment than modeled in this analysis, which may have a higher upfront cost, but further reduce energy bills over the lifetime of the equipment.

Each technology package was evaluated using DOE's EnergyPlus modeling software for the specified building prototypes and results were uniquely calculated for each of the three climate zones in Utah. The models calculated energy use on an hourly basis and details were then annualized for representation in this report.

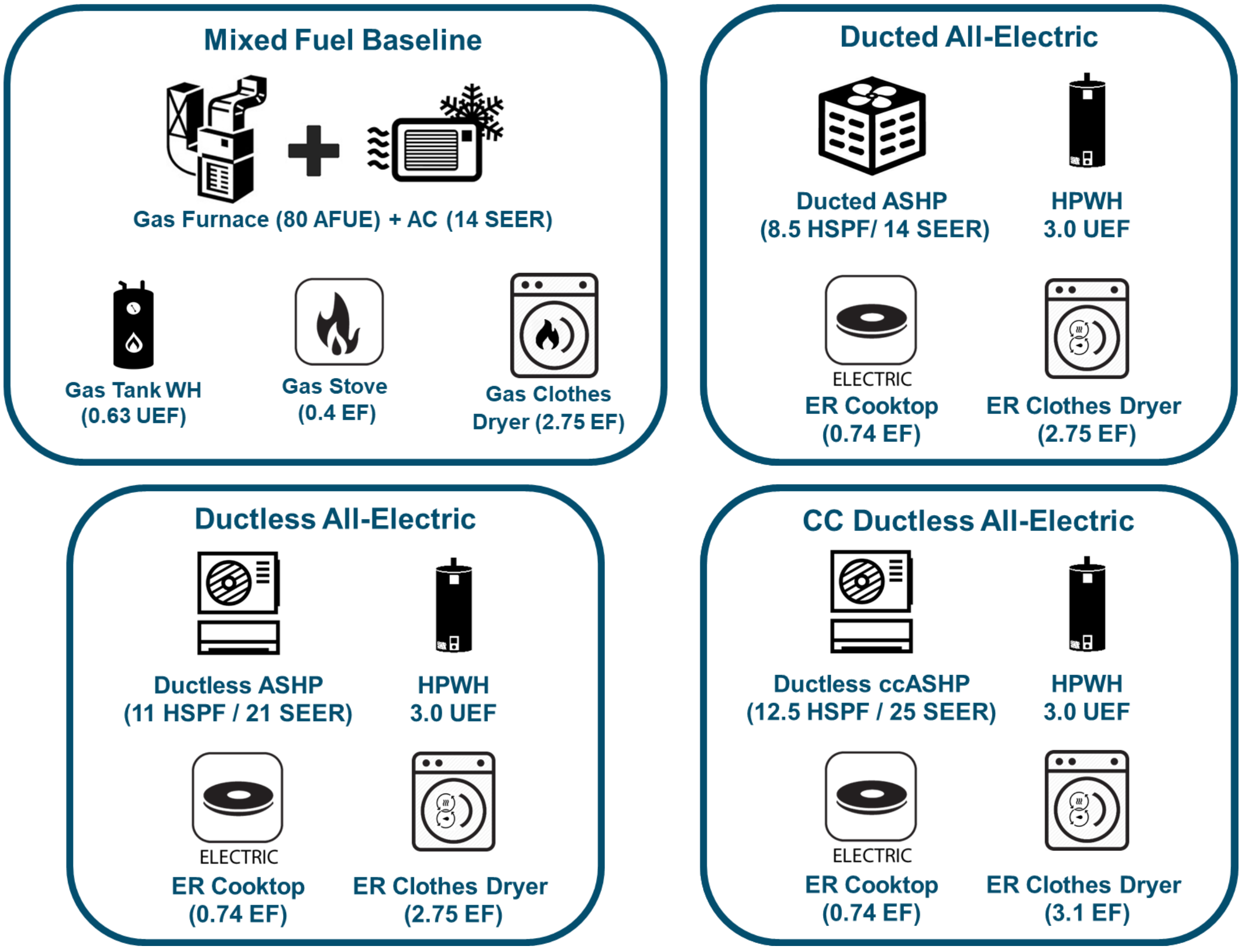


Figure 3. Summary of Technology Specifications and Assumed Rated Energy Performance for the Single-Family and Multi-Family Prototypes Modelled for this Report

2.2.1 Cold Climate Air Source Heat Pumps (ccASHPs)

Due to recent technology improvements, there is a class of commercially available air source heat pump that can provide efficient space heating, even during extremely cold temperatures. Cold climate air source heat pumps (ccASHPs) are defined as being capable of performing with a Coefficient of Performance (COP) ≥ 1.75 at 5°F[21] [22] and many available products exceed this requirement[23]. To reflect this technology option,

[21] "Cold Climate Air-Source Heat Pump Specification". Northeast Energy Efficiency Partnerships (NEEP), 2019. https://neep.org/sites/default/files/media-files/cold_climate_air-source_heat_pump_specification-version_3.1_update_.pdf

[22] ENERGY STAR Program Requirements for Central Air Conditioner and Heat Pump Equipment". Department of Energy, 2021. https://www.energystar.gov/sites/default/files/Final%20Draft%20Version%206.0%20ENERGY%20STAR%20CAC-HP%20Specification_0.pdf

[23] See NEEP Cold Climate Air Source Heat Pump Product List: https://ashp.neep.org/

ccASHPs are included in this analysis for the two colder climate zones (5B and 6B). Energy performance and costs are uniquely indicated for these ccASHP options relative to traditional ASHPs for each of these climate zones.

According to recent research from the Northwest Energy Efficiency Alliance, a new class of ductless ASHPs "…are capable of providing comfortable heating for a home when outdoor temperatures are as low as negative 15°F. These units are well suited for cold climates with little or no need for supplemental or backup heating."[24] For context, the coldest outdoor air temperature recorded at the Salt Lake City International Airport since 1990 is -12°F in 1996 and the temperature has not gone below -6°F since 2000.[25] Additionally, ASHP efficiency and performance are not affected by wind chill and therefore allow heat pumps to provide reliable space heating amidst challenging winter weather conditions.

The modelling efforts for this research report utilized a conservative approach and did not rely on data from the best performing ccASHPs available on the market. Accordingly, actual energy costs and system performance could be better than represented if contractors select the best available cold climate technologies for installation in Utah homes.

2.2.2 Technology Costs

The installed technology costs in this report reflect the estimated full cost to install a given piece of equipment in a newly constructed residential building, including primary equipment, complementary parts (e.g., wiring or piping), labor, and estimates for contractor soft costs and mark-ups. Technology costs were derived from public sources[26],[27],[28] and adjusted to reflect Utah's labor and material rates[29]. More information on technology costs for each building prototype and equipment package are included in Section 3.3 of this report. Complete cost details are available in spreadsheet format in the accompanying Utah BE Study Capital Cost Source Data zip file.

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[24] "Cold Climate DHP Specification," Northwest Energy Efficiency Alliance (NEAA), 2019, https://neea.org/our-work/cold-climate-dhp-specification

[25] "Salt Lake City – Lowest Temperature for Each Year," Current Results, Accessed 2021, https://www.currentresults.com/Yearly-Weather/USA/UT/Salt-Lake-City/extreme-annual-salt-lake-city-low-temperature.php

[26] Note: Public sources used to determine labor hours, underlying ancillary equipment needs, and with equipment costs that scale with system size. Final equipment costs were scaled by the equipment sizes determined by building energy modeling

[27] "Residential Building Electrification in California," Energy and Environmental Economics, Inc., AECOM, 2019 https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf
Capital cost data available at https://www.ethree.com/e3-quantifies-the-consumer-and-emissions-impacts-of-electrifying-california-homes/

[28] "Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code: All-Electric Multifamily Compliance Pathway," TRC, 2020. https://title24stakeholders.com/wp-content/uploads/2020/08/SF-Additions-and-Alterations_Final_-CASE-Report_Statewide-CASE-Team.pdf

[29] Note: Most primary cost data was based in California. Adjustments were made based on BLS data on relative labor and material rates. Data source: "Occupational Employment and Wage Statistics," U.S. Bureau of Labor Statistics, Accessed May 2020. https://www.bls.gov/oes/current/oessrcma.htm

2.3 Avoiding Gas Infrastructure Costs and "Electric Ready" Scenario

2.3.1 Cost Savings by Avoiding Gas Infrastructure

In addition to the appliance-related costs included in this study, there are additional construction costs for mixed fuel buildings that are important to consider.

Most notable are the costs of installing utility-side gas infrastructure for a mixed fuel property, including the gas distribution pipeline and related infrastructure to connect a building to the gas system. Given that electricity is a prerequisite for any new development, the ability to eliminate gas infrastructure in an all-electric building presents a unique opportunity to cut construction costs while still providing for energy needs. Examples of gas-related infrastructure that can be eliminated from all-electric developments include:

- Gas utility distribution lines, connections, and meters;
- Gas piping that distributes gas to appliances throughout the property;
- Certain types of venting and other infrastructure for gas equipment; and,
- Distributed ductwork which can be eliminated if the property uses ductless air-source heat pumps (a.k.a. "mini-splits") for space heating and cooling needs.

Estimates for running gas piping to each end use within a building were included in the cost estimation method for this study and are incorporated in the construction cost estimates for each appliance type. The other three types of costs indicated in the bullets above were not fully reflected in the per-appliance construction cost estimates in this study, but can result in cost, timing, and design requirements for a property which can be avoided in an all-electric building. The anticipated financial savings for avoiding gas will vary by property and utility. However, separate research has analyzed certain avoided gas infrastructure costs in various parts of the country and can help inform expectations for a future, localized analysis in a Utah:

- Research conducted by Group14 Engineering in Colorado notes that for single-family homes, "Natural gas piping and connection for new construction typically costs $5,000 - $8,000 [per building]. This includes the Xcel Energy natural gas connection fee." This study proceeded to use an average estimate of $6,500 per home for avoided gas connection and piping costs in its single-family home analysis.[30]

- RMI assumed an "out-of-pocket cost of $2,100 for the gas connection of a new home" across seven cities analyzed in a 2020 report on new construction. However, the report noted that "this estimate is conservative, as our research shows that the out-of-pocket cost range for a new

[30] "Electrification of Commercial and Residential Buildings: An evaluation of the system options, economics, and strategies to achieve electrification of buildings," Group14 Engineering, 2020, https://www.communityenergyinc.com/wp-content/uploads/Building-Electrification-Study-Group14-2020-11.09.pdf

> customer gas connection per lot is $0 to $15,000 [or more],"[31] demonstrating a wide range of potential financial impacts associated with installing gas utility connections. In some instances, a portion of the gas line extension costs are socialized and paid for by the broader ratepayer base of utility customers, thus further complicating full cost impact estimates.

The cost estimates above also do not factor in the interior space requirements and expense of HVAC ductwork, which can be avoided with an all-electric ductless air-source heat pump system for space heating and cooling. Estimates of avoided ductwork vary by location and project, but one recent assessment has suggested a range of $1,900 - $4,000 for ductwork labor and materials for a new 2,000 square foot single-family home.[32] This cost doesn't reflect the additional interior space considerations and costs associated with running ductwork throughout an attic, ceilings and walls. Avoiding ductwork by utilizing ductless air-source heat pumps also provides the benefit of enhanced energy performance and lower energy bills, as ductwork results in 20% – 30% energy losses in the typical home as air "is lost due to leaks, holes, and poorly connected ducts," according to ENERGY STAR.[33]

These findings indicate that developers in Utah and elsewhere can likely save additional construction costs above and beyond those modeled by this study by building all-electric homes and properties. Developers should investigate possible savings based on site-specific expenses and design requirements associated with providing gas infrastructure and appliances in their local market and specific situations.

2.3.2 "Electric Ready" New Construction

Alongside the growing momentum for all-electric residential properties, "Electric Ready" new construction is gaining traction as a separate but related type of construction. Electric Ready buildings include installation of the necessary electrical capacity, conduit, and wiring needed to more affordably transition to electric appliances and install EV charging infrastructure in the future, while still installing gas services upfront for some energy uses. Electric Ready properties may not have lower upfront construction costs compared to mixed fuel buildings because of the need to install additional electrical infrastructure, but they avoid major retrofit costs in the future and are gaining traction as familiarity and confidence in efficient electric appliances and electric vehicles continue to grow.

Electric readiness bolsters consumer choice by providing future flexibility to homeowners to electrify their appliances and own an electric vehicle. This improved consumer choice, along with a desire to cut local air pollution by reducing or eliminating fossil fuel combustion in homes, has elevated Electric Ready new construction as a priority solution among certain Utah stakeholders. In November 2021, Utah Clean Energy and the Salt Lake City Building Services Department co-submitted an application to the Utah Uniform Building Code Commission (UBCC) requesting a code update that would require single-family and

[31] "The New Economics of Electrifying Buildings," RMI, 2020b, https://rmi.org/insight/the-new-economics-of-electrifying-buildings/
[32] "How Much Does It Cost to Install Ductwork?," FIXR, 2021, https://www.fixr.com/costs/ductwork
[33] "Duct Sealing," ENERGY STAR, Accessed 2021, https://www.energystar.gov/campaign/heating_cooling/duct_sealing

low-rise multi-family new construction to be constructed as Electric Ready.[34] This application reflected upfront cost estimates of $925 and $1,350 for the two residential property types for achieving electric readiness. In comparison, the cost premium of retrofitting a residential building to Electric Ready outcomes was estimated to be 416% for a single-family home and 267% for a low-rise multi-family property. The Electric Ready code application is currently pending consideration by the Utah UBCC and potentially the Utah State Legislature.

2.4 Energy Utility Rates

Retail utility rates and rate structures from three Utah energy utilities—Dominion Energy, Rocky Mountain Power, and St. George Utilities—were used to calculate energy bill costs for this analysis. The utility rates utilized for modelling were based on the incumbent utility for each of the three climate zone locations referenced in Section 2.1. Hourly building energy consumption outputs from the DOE EnergyPlus model were used to estimate annual customer utility bills for each building prototype. The following tables display assumed retail utility rates, reflecting the current energy rates and rate structures of the utility providers at the time of report publication. Table 1 displays the Dominion Energy Gas Rates for General Services (applicable to all Utah climate zones). Table 2 displays Rocky Mountain Power Residential Electricity Rates (used in Utah climate zones 5B/Salt Lake City and 6B/Vernal). Table 3 displays residential electricity rates for City of St George Utilities (used in Utah climate zone 3B/St. George).

To calculate lifecycle utility costs, a 2%[35] inflation rate was assumed and a 0.75%[36] Compound Annual Growth Rate (CAGR) above inflation was incorporated for both gas and electricity rates. For the total lifecycle costs over a 15-year period, a 7% nominal discount rate was assumed for the net present value of utility bills because people are assumed to discount the value of future savings.

Table 1. Dominion Energy Utah Gas Rates[37]

Dominion Energy Utah - Gas General Service Rate			
		Apr-Oct	Nov-Mar
Energy Charge ($/therm)	Tier I (first 450 therms)	$0.794154	$0.923379
	Tier II (additional therms)	$0.666779	$0.7960005
Monthly Meter Charge – Single-Family		$6.75/customer	
Monthly Meter Charge - Multi-Family		$6.75/customer	

[34] "Electric Ready Homes: A Clean Air Innovation for Utah," Utah Clean Energy, Accessed 2021, https://utahcleanenergy.org/electric-ready-homes/

[35] The average annual US inflation rate from January 2000 through January 2020 is approximately 2%. Source: https://www.bls.gov/data/inflation_calculator.htm

[36] 0.75% Compound Annual Growth Rate is consistent with rate forecasts in the US EIA Annual Energy Outlook:

[37] "Dominion Energy Utah Tariff," Dominion Energy, 2022, https://cdn-dominionenergy-prd-001.azureedge.net/-/media/pdfs/utah/rates-and-tariffs/utah-tariff.pdf?la=en&rev=842fde2ab8af46dcaf7766a725816e25&hash=00B378D6ED0B163DE77D9313A0AE9C6A

Table 2. Rocky Mountain Power Residential Electric Rates[38]

Rocky Mountain Power Residential Service - Electric Service Schedule No. 1			
		June-Sept	Oct-May
Energy Charge ($/kWh)	Tier I (first 400 kWh)	$0.090279	$0.079893
	Tier II (additional kWh)	$0.117210	$0.103725
Monthly Meter Charge – Single-Family		$10/customer	
Monthly Meter Charge - Multi-Family		$6/customer	

Table 3. City of St George Utilities[39]

City of St George Utilities - Residential Electricity Service		
		Year-Round
Energy Charge ($/kWh)	Tier I (first 800 kWh)	$0.075053
	Tier II (additional kWh)	$0.091320
Monthly Meter Charge – Single-Family		$18.65/customer
Monthly Meter Charge - Multi-Family		$18.65/customer

[38] "Rocky Mountain Power – State of Utah Price Summary – In Effect as of January 1, 2022," Rocky Mountain Power, 2022, https://www.rockymountainpower.net/content/dam/pcorp/documents/en/rockymountainpower/rates-regulation/utah/Utah_Price_Summary.pdf

[39] "Utility Rates," City of St. George Utilities, Accessed 2022, https://www.sgcity.org/utilities/utilityrates

3 Results

This portion of the report details the construction costs, energy use, and energy bill results for the modeled new single-family and low-rise multi-family properties in each of the three primary climate zones in Utah. These results are meant to help Utah stakeholders understand estimated energy use outcomes and financial implications of all-electric new construction in Utah relative to mixed fuel properties built with both electric and gas appliances.

3.1 Building Energy Consumption

Building energy modeling outputs are reported using site energy use[40], with results disaggregated by fuel type and for each end use technology. Site energy use was evaluated by converting both electricity consumption and gas consumption to a single common metric: Million British Thermal Units (MMBtu). Source energy[41] modelling was not completed for this analysis due to the changing dynamics of utility-scale electricity generation and more complicated lifecycle implications of both electricity and gas service. The results for single-family and low-rise multi-family properties are reflected in Figure 4 and Figure 5 below.

Based on the results of the energy models, all-electric homes consume significantly less site energy than mixed fuel homes on a per-unit basis. The primary driver of this outcome is the fact that electric heat pump appliances have much a higher onsite efficiency than their gas counterparts.

Figure 4 indicates that the ductless heat pump package consumes less site energy than ducted heat pumps, in part due to avoided fan energy consumption with ductless heat pumps. Avoiding HVAC ductwork has the additional benefit of eliminating leaks, holes and poorly connected ducts, which result in 20% – 30% energy losses in the typical home as cited earlier.

Generally, homes in colder climates consume more energy due to increased space heating demands and the modelling results indicate higher annual site energy use in buildings located in colder Utah climate zones. Additionally, the efficiency of air-source heat pump systems is impacted by cold weather and as temperature drops then heating efficiency decreases. When temperatures became very cold, the modelling assumed that non-cold climate heat pumps would be supplemented by electric resistance space heating in climate zones 5B and 6B. However, in spite of these performance losses, the all-electric scenarios still result in lower site energy consumption than mixed fuel buildings that rely on gas for space heating and water heating.

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40 Note: site energy is not intended to be used as a metric of environmental performance in this report; it is intended as a more direct way to display outputs of the building energy models

41 In this report, site energy refers to energy that is consumed on site at a building. Source energy refers to all of the raw fuels required to operate the building, incorporating losses with transmission, distribution, and production. For additional details, see: https://www.energystar.gov/buildings/benchmark/understand_metrics/source_site_difference

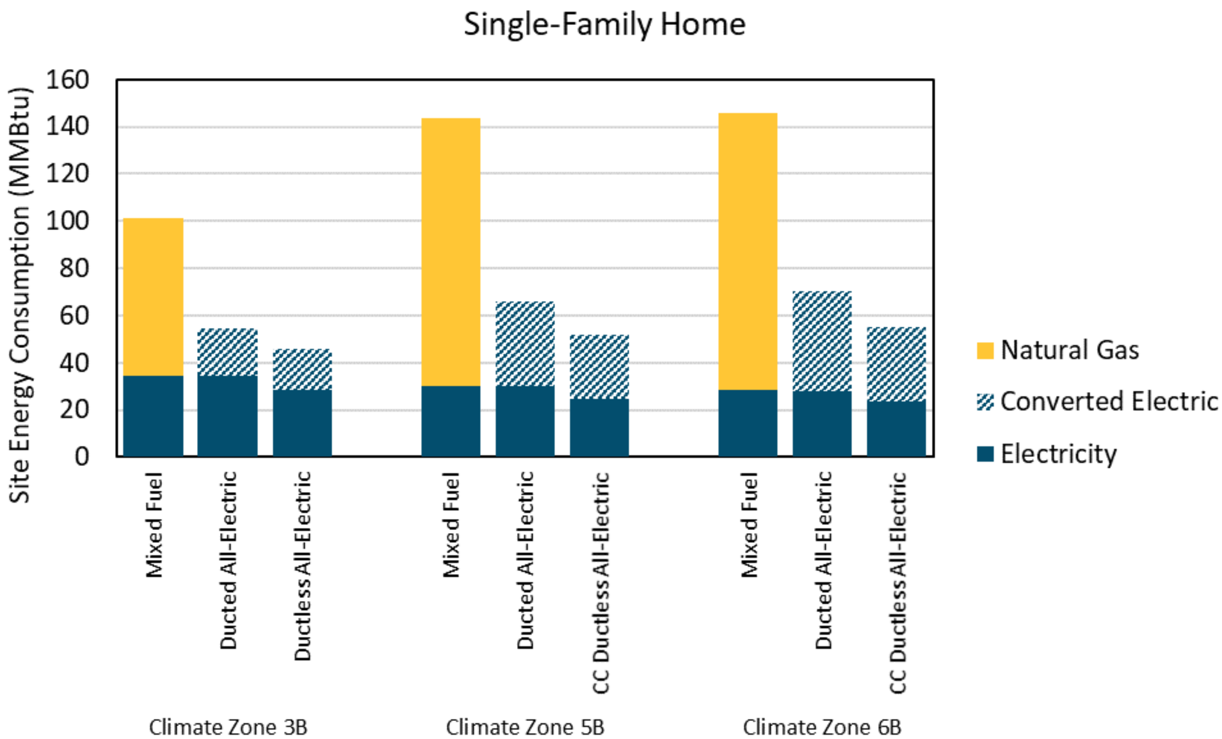

Figure 4. Site Energy Consumption by Climate Zone and Technology Package for the Single-Family Home Prototype. "Electrified Loads" in all-electric buildings reflect the energy loads that are served by gas in the mixed fuel buildings, including space heating, water heating, cooking, and clothes drying. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

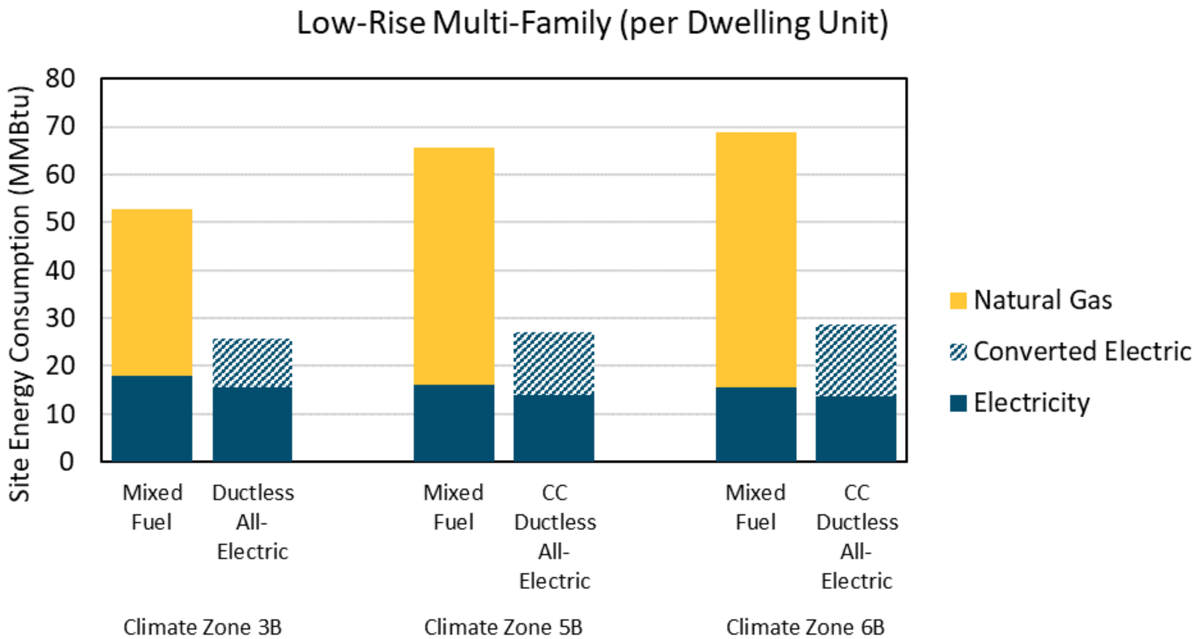

Figure 5. Site Energy Consumption by Climate Zone and Technology Package for the Multi-Family Building Prototype (normalized by Dwelling Unit). "Electrified Loads" in all-electric buildings reflect the energy loads that are served by gas in the mixed fuel buildings, including space heating, water heating, cooking, and clothes drying. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

3.2 First Year Energy Bills

Energy bill impacts were calculated based on modeled site energy consumption multiplied by local utility rates. While the site energy consumption is much lower for every all-electric technology package, the estimated energy bills are closer between the all-electric and mixed fuel development types. However, in most scenarios across all Utah climate zones, the all-electric building results in lower energy bill costs than the mixed fuel building (see Figures 6 and 7).

In the warmer region of Climate Zone 3B in Utah (St. George), all of the all-electric technology packages resulted in lower annual energy bills relative to a property with gas equipment for both single-family homes and low-rise multi-family buildings. Modelling for Climate Zone 3B uniquely leveraged City of St. George Utilities rates, which has lower wintertime retail electricity rates than Rocky Mountain Power and helps further improve the economics of all-electric homes in this region.

For single-family homes in the colder climate zones further north in Utah (Climate Zones 5B and 6B), the ducted ASHP package has slightly higher first-year energy bills, which is due to the higher costs of space heating and a partial reliance on backup electric resistance heat on the coldest days. All-electric new construction using a *ductless* ASHP package (or a *cold climate ductless heat pump* in colder regions) is estimated to result in lower energy bills for all scenarios in all climate zones relative to a mixed fuel single-family home because these systems are more efficient than their *ducted* ASHP counterparts.

For low-rise multi-family properties there are similar opportunities to reduce energy bills by pursuing all-electric new construction. Only ductless ASHPs were modeled for this property types; first-year annual energy costs for all-electric properties were lower than mixed fuel properties in all of the climate zones evaluated across every climate zone.

One additional energy bill benefit of all-electric new construction for both single-family and multi-family properties is the elimination of a fixed monthly gas charge. This is reflected in the modelling and improves consumer economics in all-electric properties and helps sustain positive bill impacts for owners and renters responsible for paying the energy bill.

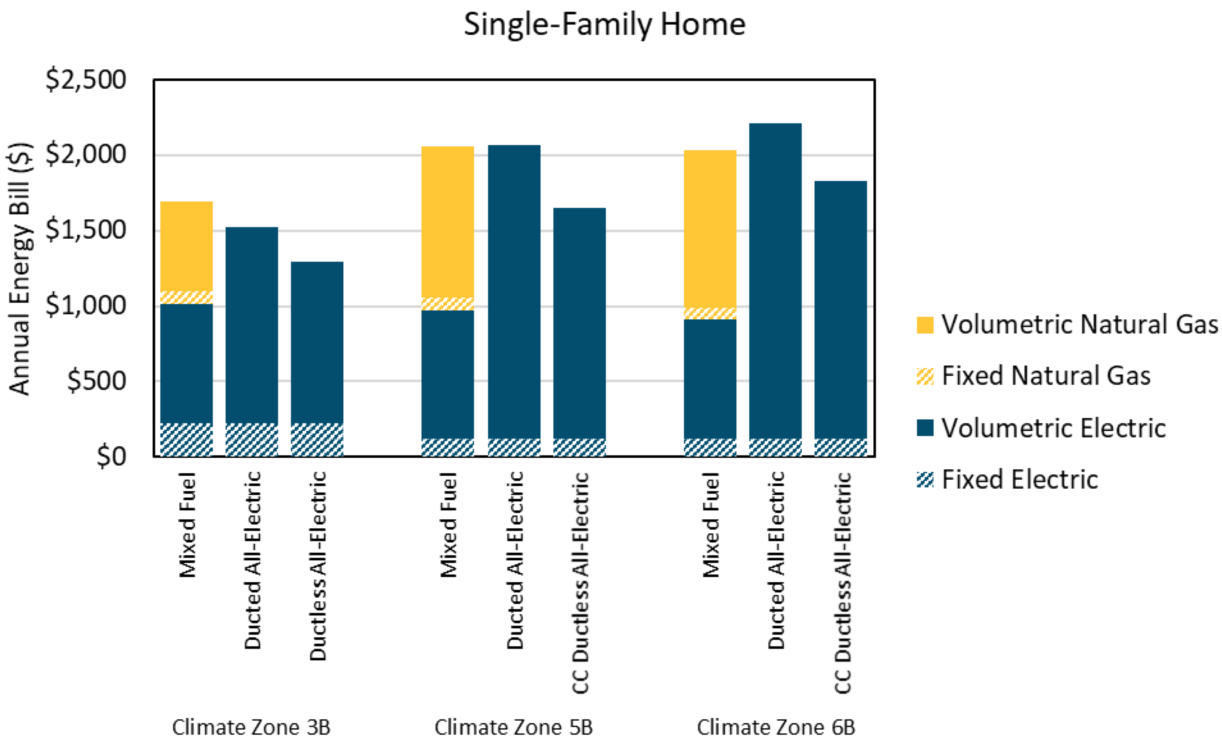

Figure 6. First-year Annual Energy Bills by Climate Zone and Technology Package for the Single-Family Home Prototype. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

Table 4. Quantified Results From Figure 6

First Year Energy Bills		**Gas**		**Electricity**		**Total**
		Fixed Charge	Volumetric Charges	Fixed Charge	Volumetric Charges	
CZ 3B (St George)	Mixed Fuel	$81	$591	$224	$792	$1,688
	Ducted All-Electric	$0	$0	$224	$1,297	$1,520
	Ductless All-Electric	$0	$0	$224	$1,068	$1,292
CZ 5B (Salt Lake City)	Mixed Fuel	$81	$1,006	$120	$852	$2,059
	Ducted All-Electric	$0	$0	$120	$1,948	$2,068
	CC Ductless All-Electric	$0	$0	$120	$1,511	$1,631
CZ 6B (Vernal)	Mixed Fuel	$81	$1,040	$120	$788	$2,029
	Ducted All-Electric	$0	$0	$120	$2,089	$2,209
	CC Ductless All-Electric	$0	$0	$120	$1,614	$1,734

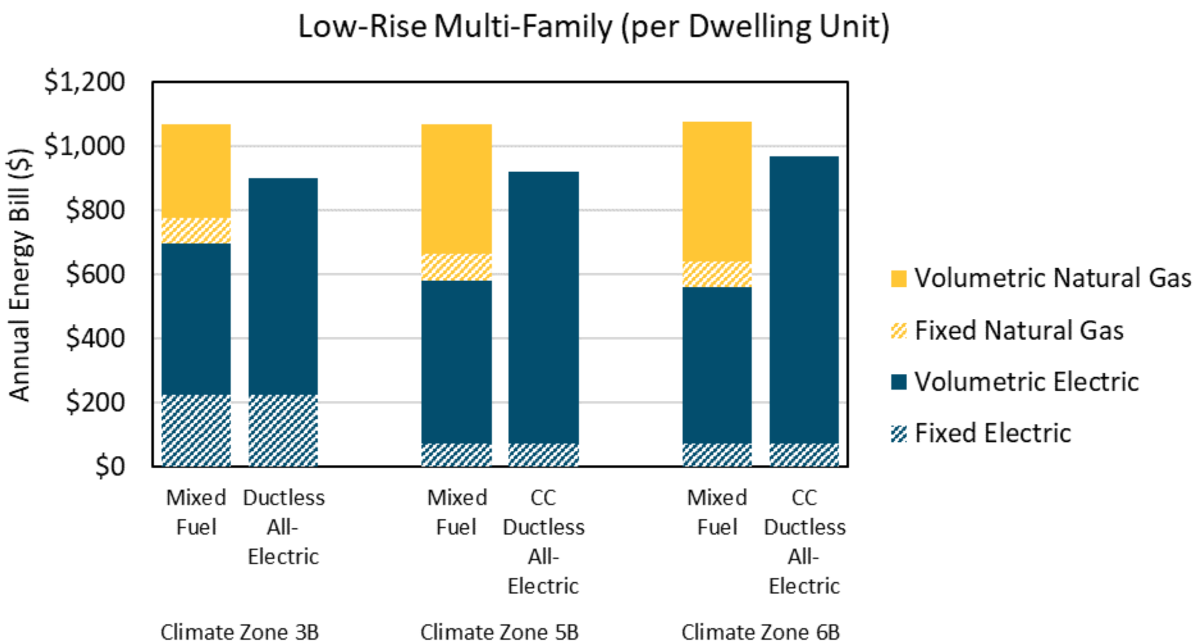

Figure 7. First-year Annual Energy Bills by Climate Zone and Technology Package for the Multi-Family Building Prototype (normalized by Dwelling Unit). CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

Table 5. Quantified Results from Figure 7. Costs are reflected on a per dwelling unit basis.

First Year Energy Bills, per dwelling unit		**Gas**		**Electricity**		**Total**
		Fixed Charge	Volumetric Charges	Fixed Charge	Volumetric Charges	
CZ 3B (St George)	Mixed Fuel	$81	$292	$224	$472	$1,069
	Ductless All-Electric	$0	$0	$224	$679	$902
CZ 5B (Salt Lake City)	Mixed Fuel	$81	$406	$72	$511	$1,069
	CC Ductless All-Electric	$0	$0	$72	$851	$923
CZ 6B (Vernal)	Mixed Fuel	$81	$435	$72	$488	$1,076
	CC Ductless All-Electric	$0	$0	$72	$897	$969

3.3 Installed Technology Costs

The installed costs associated with HVAC, water heating, cooking, and clothes dryer equipment for newly constructed all-electric and mixed fuel properties were also evaluated for this report. These equipment types were evaluated because they represent the primary electric versus gas options for newly constructed buildings.

The analysis found that installed costs for all-electric residential buildings can be comparable or even lower than the costs of constructing mixed fuel residential buildings. This finding holds true for both single-family homes and low-rise multi-family properties and across all three climate zones in Utah (see Figures 8 and 9). Ducted ASHP systems reduce installed costs across all scenarios relative to the mixed fuel building, while ductless and cold climate ductless ASHPs reduce costs in some scenarios even prior to accounting for additional avoided gas utility connection costs (a.k.a. “line extensions”) that were not quantified in this portion of the analysis.

One major driver of these reduced installation costs is the ability for heat pumps to provide both space heating and cooling, thus reducing the amount of equipment and installation costs compared to a mixed fuel building where two separate pieces of equipment must be installed for heating and cooling (typically a gas furnace and a central air conditioner). Prior to accounting for gas utility connection costs, ductless ASHPs may have higher installation costs, primarily driven by the installation of refrigerant piping in homes. Packages with cold climate ductless ASHP options were found to have an installation cost premium in single-family homes prior to considering additional avoided gas infrastructure costs, but these packages are lower cost to install in multi-family properties. As reflected in the prior section of this report, the ductless ASHP scenarios modeled provide annual energy bill savings for every scenario.

Across the other types of equipment that were evaluated for this report (water heating, cooking, and clothes dryer equipment), costs were generally similar for all-electric equipment relative to gas-fueled options.

As noted in Section 2.3.1, there are also additional cost implications of installing gas distribution lines, and other related infrastructure in mixed fuel buildings, but these financial impacts are less clear and require site-specific evaluation and consideration of local utility line extension rules. For purposes of this study, we did not attempt to quantify and include typical gas line extension charges in Utah. However, property developers are encouraged to consult local utility rules and site-specific design plans for a more tailored estimate of anticipated gas utility connection costs (a.k.a. “line extensions”) for any individual project.

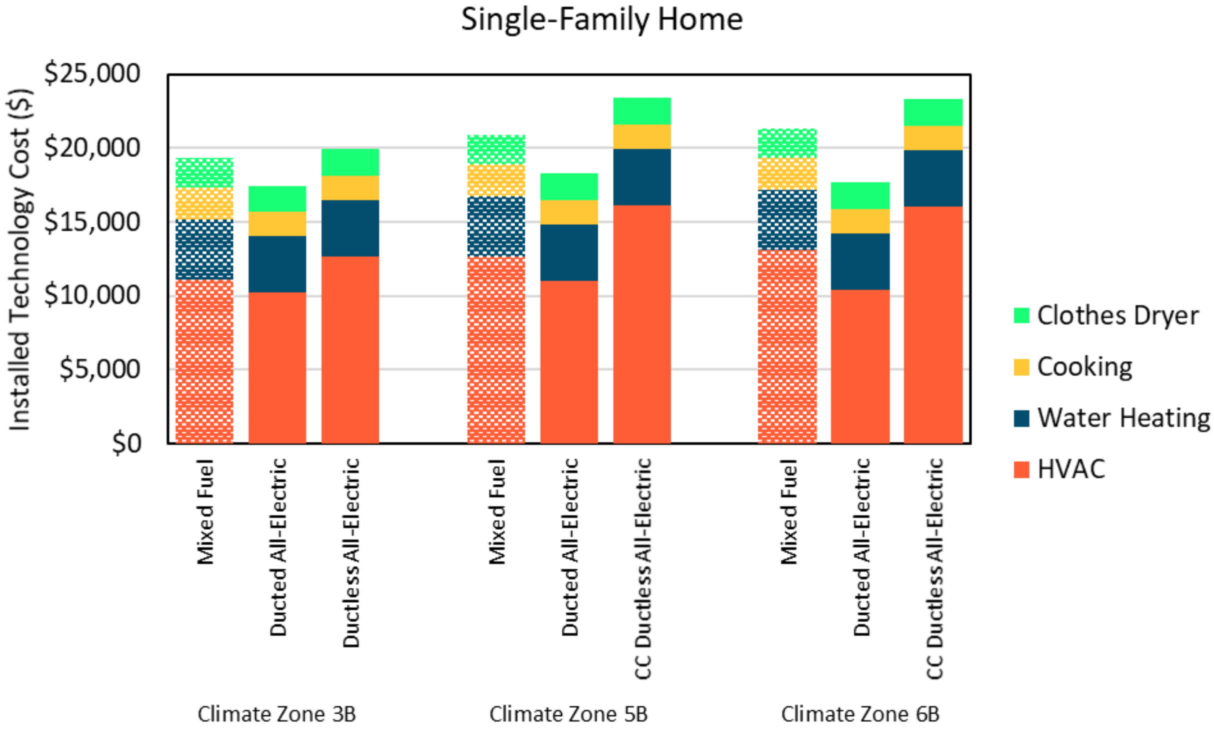

Figure 8. Installed Technology Costs by Climate Zone and Technology Package for the Single-Family Home Prototype. Hatched area in bar charts denotes the counterfactual mixed-fuel building. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

Table 6. Quantified Results for Figure 8. See Section 2.3.1 for further details on additional gas infrastructure costs not reflected below.

Capital Costs		HVAC	Water Heating	Cooking	Clothes Dryer	Gas Utility Line Extension Costs	Total
CZ 3B (St George)	Mixed Fuel	$11,099	$4,057	$2,166	$2,029	*TBD*	$19,350
	Ducted All-Electric	$10,180	$3,873	$1,610	$1,802	$0	$17,465
	Ductless All-Electric	$12,618	$3,873	$1,610	$1,802	$0	$19,902
CZ 5B (Salt Lake City)	Mixed Fuel	$12,677	$4,057	$2,166	$2,029	*TBD*	$20,929
	Ducted All-Electric	$10,966	$3,873	$1,610	$1,802	$0	$18,251
	CC Ductless All-Electric	$16,084	$3,873	$1,610	$1,802	$0	$23,369
CZ 6B (Vernal)	Mixed Fuel	$13,103	$4,057	$2,166	$2,029	*TBD*	$21,355
	Ducted All-Electric	$10,376	$3,873	$1,610	$1,802	$0	$17,661
	CC Ductless All-Electric	$16,004	$3,873	$1,610	$1,802	$0	$23,289

This table includes all costs incurred to install the specified equipment, including materials, labor, contractor markups, and other ancillary installation costs such as running wiring/piping, pouring concrete pads where needed, etc. CC Ductless All-Electric represents packages with a Cold Climate Ductless Heat Pump.

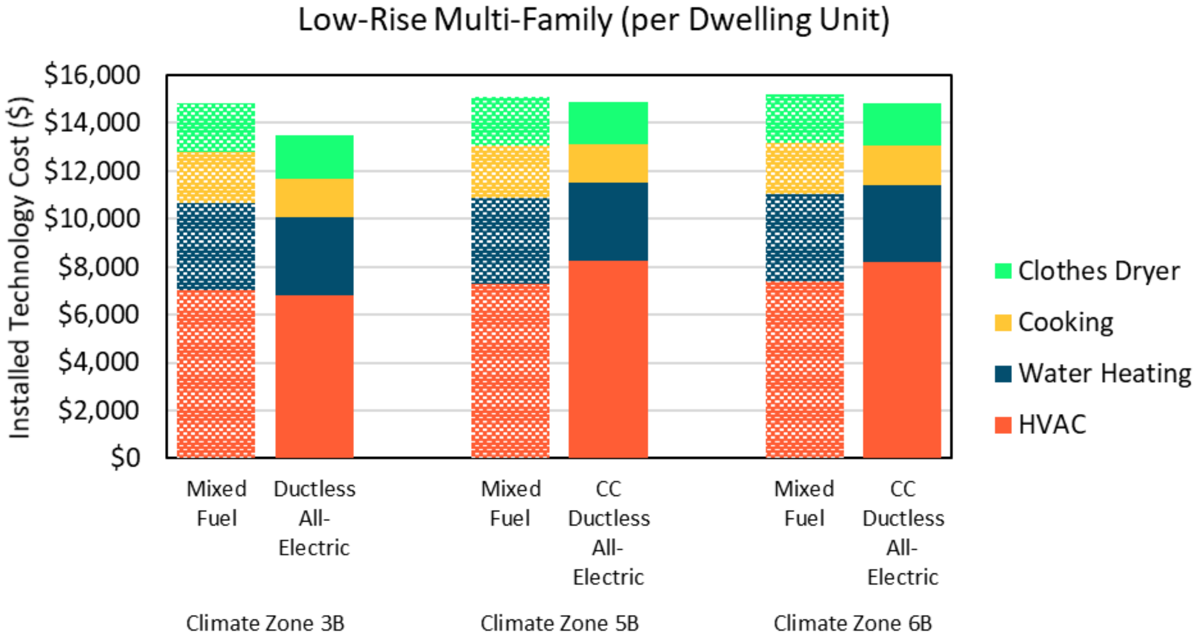

Figure 9. Installed Technology Cost by Climate Zone and Technology Package for the Multi-Family Building Prototype (normalized by Dwelling Unit). Hatched area in bar charts denotes the counterfactual mixed-fuel building. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

Table 7. Quantified Results for Figure 9. See Section 2.3.1 for further details on additional gas infrastructure costs not reflected below.

Capital Costs		HVAC	Water Heating	Cooking	Clothes Dryer	Gas Utility Line Extension Costs	Total
CZ 3B (St George)	Mixed Fuel	$7,032	$3,601	$2,166	$2,029	*TBD*	$14,827
	Ductless All-Electric	$6,819	$3,244	$1,610	$1,802	$0	$13,474
CZ 5B (Salt Lake City)	Mixed Fuel	$7,280	$3,601	$2,166	$2,029	*TBD*	$15,075
	CC Ductless All-Electric	$8,243	$3,244	$1,610	$1,802	$0	$14,898
CZ 6B (Vernal)	Mixed Fuel	$7,411	$3,601	$2,166	$2,029	*TBD*	$15,207
	CC Ductless All-Electric	$8,185	$3,244	$1,610	$1,802	$0	$14,840

This table includes all costs incurred to install the specified equipment, including materials, labor, contractor markups, and other ancillary installation costs such as running wiring/piping, pouring concrete pads where needed, etc. CC Ductless All-Electric represents packages with a Cold Climate Ductless Heat Pump.

3.4 Net Present Value Lifecycle Cost

The lifecycle cost of all-electric and mixed fuel residential construction includes the combined costs of both the installation costs and annualized energy bill impacts. To identify the lifecycle cost, this analysis calculates the net present value (NPV) of the installed costs of gas and electric equipment and the total energy bill costs over 15 years of operation, assuming an annual 7% discount rate for savings.

Based on a lifecycle cost analysis, all-electric residential new construction in Utah is generally more cost-effective than mixed fuel properties for both newly constructed single-family homes and low-rise multi-family buildings in Utah. The two warmer climate zones (Climate Zones 3B and 5B), home to most of the state's population, have the most favorable lifecycle economics for all-electric new construction in both single-family and multi-family buildings.

Across all scenarios analyzed, all-electric ASHP packages have the lowest lifecycle costs and present the best overall financial outcomes. Financial outcomes in ductless ASHP packages are driven by significant bill savings and in cold climates it is important to specify cold climate ductless heat pumps to avoid electric resistance baseboard heating. The ducted ASHP packages for single-family homes have lower lifecycle costs than the mixed fuel homes, which is partially driven by the lowest upfront construction costs as described in Section 3.3.

As noted in Section 3.3, there are additional gas infrastructure-related costs that will be incurred in the mixed fuel scenarios, but estimating these impacts requires a site-specific evaluation and consideration of the prevailing utility line extension requirements. Property developers are encouraged to consult local utility rules and site-specific design plans for a more tailored estimate of anticipated gas utility connection costs (a.k.a. "line extensions") for any individual project.

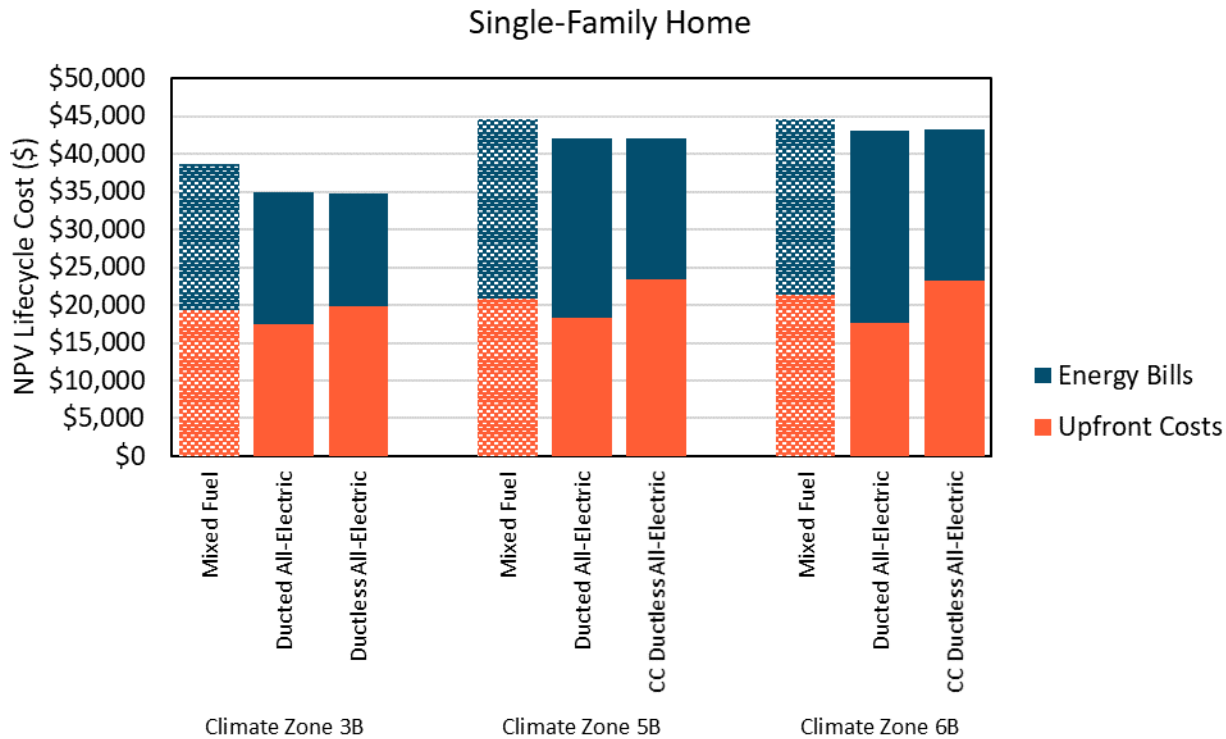

Figure 10. Present Value Lifecycle Costs Over a 15-year Time Horizon by Climate Zone and Technology Package for the Single-Family Home Prototype. CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

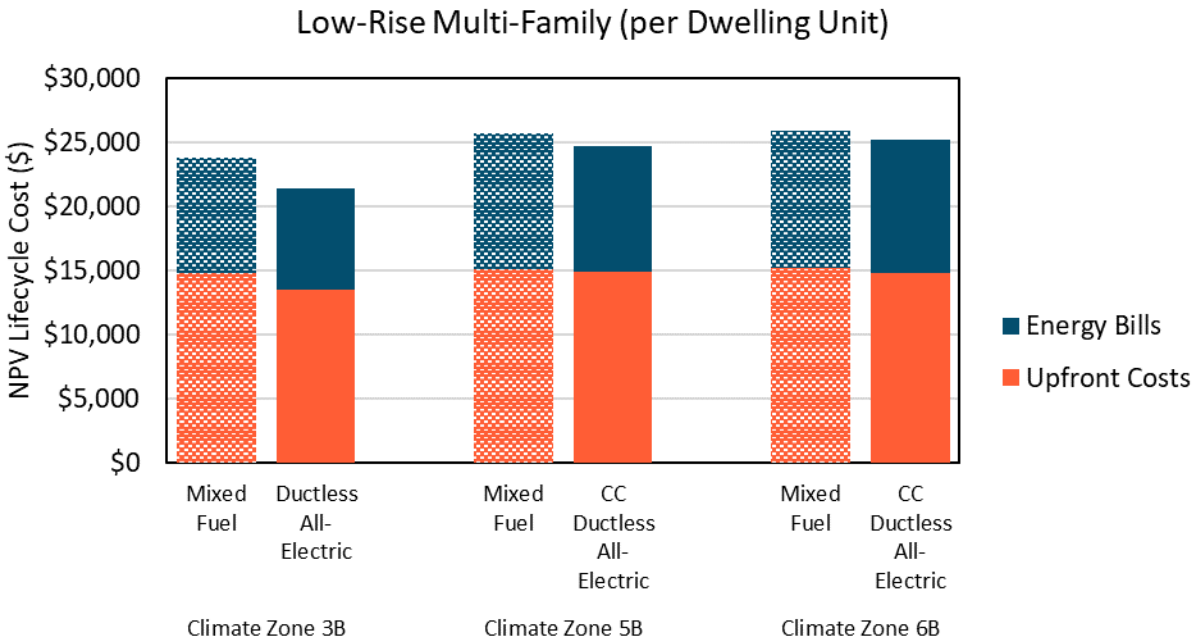

Figure 11. Present Value Lifecycle Costs Over a 15-year Time Horizon by Climate Zone and Technology Package for the Multi-Family Building Prototype (normalized by Dwelling Unit). CC Ductless All-Electric represents packages with a cold climate ductless heat pump.

4 Conclusion

This study focused on the financial implications of building all-electric new single-family and low-rise multi-family homes in Utah relative to building mixed fuel properties that include both electric and gas appliances. The results revealed opportunities to construct residential buildings in Utah at a lower cost with efficient all-electric equipment relative to a mixed fuel building. In most cases, energy bills will also decline with all-electric equipment or will be competitive to the energy costs in a mixed fuel building. This is true because all-electric heat pump technology is significantly more energy efficient than gas heating equipment.

The results demonstrated opportunities across all three modeled climate zones in Utah to develop all-electric residential properties that have lower lifecycle financial costs, which consider both the upfront construction costs and ongoing utility bill impacts, compared to mixed fuel properties. These beneficial outcomes can be maximized through intentional selection of equipment that balances upfront costs alongside energy performance. Buildings with ductless ASHP systems resulted in the best lifecycle financial performance across all scenarios, with ductless *cold climate* ASHPs also proving to be important in colder parts of the state if the goal is to maximize energy bill savings and carbon emissions reductions. The lifecycle savings of every all-electric scenario can also be further improved if the avoided costs of gas infrastructure are fully accounted for.

In addition to the financial implications of all-electric new construction, there are other beneficial outcomes for all-electric developments in Utah. These include the potential for improved outdoor and indoor air quality, reduced carbon emissions, enhanced electric grid interactivity, and other energy system benefits such as avoided gas infrastructure and maintenance costs associated with new gas utility distribution pipelines. These benefits can be realized and scaled in Utah as more property developers and households recognize the technological and market readiness of electric technologies and begin to build more all-electric properties across the state.

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6 Appendix

6.1 Single-Family Results

Energy Demand (MMBtu)		CZ 3B (St George)			CZ 5B (Salt Lake City)			CZ 6B (Vernal)		
Fuel Type	End Use	Mixed Fuel	Ducted All-Electric	Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric
Gas	Space Heating	42.5	0.0	0.0	85.0	0.0	0.0	87.4	0.0	0.0
	Water Heating	14.5	0.0	0.0	18.8	0.0	0.0	20.6	0.0	0.0
	Cooking	5.2	0.0	0.0	5.2	0.0	0.0	5.2	0.0	0.0
	Clothes Dryer	4.6	0.0	0.0	4.6	0.0	0.0	4.6	0.0	0.0
Electricity	Space Heating	0.0	11.3	8.7	0.0	26.2	17.7	0.0	32.5	21.7
	Space Cooling	11.9	11.6	7.8	7.0	6.8	3.8	5.6	5.4	3.1
	Water Heating	0.0	3.0	3.0	0.0	3.9	3.9	0.0	4.3	4.3
	Cooking	0.0	2.8	2.8	0.0	2.8	2.8	0.0	2.8	2.8
	Clothes Dryer	0.0	2.8	2.8	0.0	2.8	2.8	0.0	2.8	2.8
	Fans	2.8	2.8	0.7	3.3	3.3	0.8	2.8	2.8	0.7
	Plug Loads	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Total		101.4	54.3	45.8	143.7	65.7	51.8	146.0	70.5	55.3

First Year Energy Bills		CZ 3B (St George)			CZ 5B (Salt Lake City)			CZ 6B (Vernal)		
Fuel Type	End Use	Mixed Fuel	Ducted All-Electric	Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric
Gas	Fixed Charge	$81	$0	$0	$81	$0	$0	$81	$0	$0
	Space Heating	$383	$0	$0	$762	$0	$0	$781	$0	$0
	Water Heating	$125	$0	$0	$161	$0	$0	$176	$0	$0
	Cooking	$44	$0	$0	$44	$0	$0	$44	$0	$0
	Clothes Dryer	$39	$0	$0	$39	$0	$0	$39	$0	$0
Electricity	Fixed Charge	$224	$224	$224	$120	$120	$120	$120	$120	$120
	Space Heating	$0	$270	$205	$0	$761	$508	$0	$949	$626
	Space Cooling	$278	$279	$181	$213	$215	$118	$167	$169	$93
	Water Heating	$0	$72	$70	$0	$115	$113	$0	$126	$124
	Cooking	$0	$66	$65	$0	$83	$81	$0	$83	$82
	Clothes Dryer	$0	$68	$66	$0	$85	$83	$0	$85	$83
	Fans	$63	$66	$16	$89	$97	$24	$75	$83	$20
	Plug Loads	$451	$475	$465	$550	$593	$584	$546	$594	$585
Total		$1,688	$1,520	$1,292	$2,059	$2,068	$1,631	$2,029	$2,209	$1,734

Capital Costs	CZ 3B (St George)			CZ 5B (Salt Lake City)			CZ 6B (Vernal)		
End Use	Mixed Fuel	Ducted All-Electric	Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric
Space Heating	$11,099	$10,180	$12,618	$12,677	$10,966	$16,084	$13,103	$10,376	$16,004
Space Cooling	$0	$0	$0	$0	$0	$0	$0	$0	$0
Water Heating	$4,057	$3,873	$3,873	$4,057	$3,873	$3,873	$4,057	$3,873	$3,873
Cooking	$2,166	$1,610	$1,610	$2,166	$1,610	$1,610	$2,166	$1,610	$1,610
Clothes Dryer	$2,029	$1,802	$1,802	$2,029	$1,802	$1,802	$2,029	$1,802	$1,802
Fans	$0	$0	$0	$0	$0	$0	$0	$0	$0
Gas Infrastructure	*TBD*	$0	$0	*TBD*	$0	$0	*TBD*	$0	$0
Total	$19,350	$17,465	$19,902	$20,929	$18,251	$23,369	$21,355	$17,661	$23,289

NPV Lifecycle	CZ 3B (St George)			CZ 5B (Salt Lake City)			CZ 6B (Vernal)		
Fuel Type	Mixed Fuel	Ducted All-Electric	Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric	Mixed Fuel	Ducted All-Electric	CC Ductless All-Electric
Electric Bill NPV	$11,660	$17,452	$14,834	$11,163	$23,733	$18,720	$10,425	$25,356	$19,901
Gas Bill NPV	$7,713	$0	$0	$12,473	$0	$0	$12,865	$0	$0
Total Upfront Costs	$19,890	$18,005	$20,442	$21,469	$18,791	$23,909	$21,895	$18,201	$23,829
Total Lifecycle Cost	$39,263	$35,457	$35,276	$45,104	$42,524	$42,629	$45,185	$43,556	$43,730

6.2 Multi-Family Results – All Figures Reflected on a "Per Dwelling Unit" Basis

Energy Demand (MMBtu)		CZ 3B (St George)		CZ 5B (Salt Lake City)		CZ 6B (Vernal)	
Fuel Type	End Use	Mixed Fuel	Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric
Gas	Space Heating	15.1	0.0	26.4	0.0	29.0	0.0
	Water Heating	11.6	0.0	14.9	0.0	16.4	0.0
	Cooking	4.3	0.0	4.3	0.0	4.3	0.0
	Clothes Dryer	3.8	0.0	3.8	0.0	3.8	0.0
Electricity	Space Heating	0.0	3.0	0.0	5.3	0.0	6.9
	Space Cooling	4.6	3.2	2.7	1.6	2.2	1.3
	Water Heating	0.0	2.4	0.0	3.1	0.0	3.4
	Cooking	0.0	2.3	0.0	2.3	0.0	2.3
	Clothes Dryer	0.0	2.4	0.0	2.4	0.0	2.4
	Fans	1.2	0.3	1.3	0.3	1.2	0.3
	Plug Loads	12.1	12.1	12.1	12.1	12.1	12.1
Total		52.7	25.7	65.6	27.1	68.9	28.7

First Year Energy Bills, per dwelling unit		CZ 3B (St George)		CZ 5B (Salt Lake City)		CZ 6B (Vernal)	
Fuel Type	End Use	Mixed Fuel	Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric
Gas	Fixed Charge	$81	$0	$81	$0	$81	$0
	Space Heating	$128	$0	$219	$0	$238	$0
	Water Heating	$97	$0	$121	$0	$132	$0
	Cooking	$36	$0	$35	$0	$34	$0
	Clothes Dryer	$32	$0	$31	$0	$31	$0
Electricity	Fixed Charge	$224	$224	$72	$72	$72	$72
	Space Heating	$0	$79	$0	$163	$0	$211
	Space Cooling	$123	$84	$91	$53	$72	$42
	Water Heating	$0	$63	$0	$96	$0	$106
	Cooking	$0	$61	$0	$73	$0	$73
	Clothes Dryer	$0	$63	$0	$75	$0	$75
	Fans	$31	$8	$40	$10	$37	$9
	Plug Loads	$318	$320	$379	$381	$379	$381
Total		$1,069	$902	$1,069	$923	$1,076	$969

Capital Costs	CZ 3B (St George)		CZ 5B (Salt Lake City)		CZ 6B (Vernal)	
End Use	Mixed Fuel	Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric
HVAC	$7,032	$6,819	$7,280	$8,243	$7,411	$8,185
Space Cooling	$0	$0	$0	$0	$0	$0
Water Heating	$3,601	$3,244	$3,601	$3,244	$3,601	$3,244
Cooking	$2,166	$1,610	$2,166	$1,610	$2,166	$1,610
Clothes Dryer	$2,029	$1,802	$2,029	$1,802	$2,029	$1,802
Fans	$0	$0	$0	$0	$0	$0
Gas Infrastructure	*TBD*	$0	*TBD*	$0	*TBD*	$0
Total	$14,827	$13,474	$15,075	$14,898	$15,207	$14,840

NPV Lifecycle	CZ 3B (St George)		CZ 5B (Salt Lake City)		CZ 6B (Vernal)	
Fuel Type	Mixed Fuel	Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric	Mixed Fuel	CC Ductless All-Electric
Electric Bill NPV	$5,557	$7,933	$5,939	$9,848	$5,679	$10,376
Gas Bill NPV	$3,409	$0	$4,709	$0	$5,044	$0
Total Upfront Costs	$14,914	$13,561	$15,162	$14,985	$15,294	$14,927
Total Lifecycle Cost	$23,880	$21,494	$25,811	$24,833	$26,017	$25,303