



# BENEFITS OF HEAT PUMPS FOR COLORADO HOMES

## 2022 Analysis

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SOUTHWEST ENERGY EFFICIENCY PROJECT

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## ABOUT SWEEP

The Southwest Energy Efficiency Project is a public interest organization dedicated to advancing energy efficiency in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. For more information, visit: [swenergy.org](http://swenergy.org).

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# CHANGING LANDSCAPE FOR BUILDING ELECTRIFICATION

Beneficial electrification is an important element of Colorado’s and the United States’ efforts to significantly reduce greenhouse gas (GHG) emissions in order to mitigate the effects of climate change. In addition to achieving GHG emission reductions through converting fossil fuel uses to efficient electric technologies, other elements of beneficial electrification include reducing “societal costs” and improving the utilization of grid resources.<sup>1</sup> For residential and commercial buildings, the two largest fuel use applications are space heating and water heating.

The purpose of the Southwest Energy Efficiency Project’s (SWEET) brief report is to provide an updated analysis of the economics and GHG emissions benefits of air-source heat pumps and heat pump water heaters (HPWHs) in Colorado, for an average size, single-family home. We include both new home and retrofit scenarios. For both cost-effectiveness and the climate benefits, we are comparing the heat pump systems versus gas space or water heating. It is already clear that compared to propane or electric resistance space and water heating, heat pumps significantly reduce annual energy costs and reduce GHG emissions, so we did not update those comparisons.<sup>2</sup> In addition, there are only about 100,000 homes with propane heating in Colorado, while about 1,800,000 homes have gas heating.<sup>3</sup> Currently, only about 2-3% of Colorado homes have air- or ground-source heat pumps.<sup>4</sup> We are not including multi-family housing in this study, but several organizations will be working on recommendations for multi-family housing in the coming year.<sup>5</sup>

## MARKET CHANGES AFFECTING HEAT PUMPS

In 2018, SWEET released “[Benefits of Heat Pumps for Homes in the Southwest](#),” which provided our analysis of the possible cost and GHG emission reduction benefits of heat pumps, in both new homes and in retrofit applications, for five Southwest cities representing a variety of climates. A number of things have changed in the last three years: heat pump technology has continued to improve, and SWEET and many other supporters of building electrification have a better understanding of the best applications of heat pumps as well as limitations.

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<sup>1</sup> This definition is from Colorado Senate Bill 246, passed in 2021, <https://leg.colorado.gov/bills/sb21-246>. Societal costs mean the life-cycle costs of beneficial electrification measures for the consumer, plus the social costs of carbon dioxide and methane. The Beneficial Electrification League (BEL) has a similar but slightly different definition of beneficial electrification. See <https://be-league.com/>.

<sup>2</sup> For recent comparisons of heat pumps and HPWHs vs. propane or electric resistance, see <https://loveelectric.org/heating-cooling/> and <https://loveelectric.org/hot-water/>.

<sup>3</sup> The number of homes with propane estimate is from the Colorado Energy Office, and the number of homes with gas heating is from EIA.

<sup>4</sup> This is based on survey data from Tri-State, Black Hills, and Xcel Energy. In addition, although data is sparse, we assume the current rate of replacement of propane furnaces or central AC systems with heat pumps is also less than 5%.

<sup>5</sup> For example, the Colorado Energy Office and BEL-CO will be putting together a sub-group to develop recommendations to support highly efficient all-electric affordable multi-family housing in 2022.

Another important change is that gas prices have increased significantly in the past six months.<sup>6</sup> While generally support for building electrification has grown, some groups, such as the gas industry, have questioned whether heat pumps are cost-effective for homeowners and whether they reduce GHG emissions compared to efficient gas furnaces.<sup>7</sup> Therefore, we decided to refresh our analysis and provide some updated recommendations. In this report we focus on Colorado municipalities, and in a subsequent report, we will include other Southwest cities.

For this analysis, we are updating the following types of information:

- The best applications for heat pumps and HPWHs in new homes and existing homes with gas heating.
- Utility rates for electricity and gas in three Colorado cities.
- Projected 15-year GHG emission factors for Colorado's electricity grid.
- New state policies affecting building electrification and utility rebates for heat pumps and HPWHs.
- New proposed federal financial incentives for heat pumps and HPWHs.

Based on our findings, SWEEP is providing several recommendations for Colorado utility programs, the Colorado Public Utilities Commission (PUC), and the federal government, to help move the state forward in meeting its climate objectives for the buildings sector.

## GROWING SUPPORT FOR ELECTRIFICATION

In the past three years, state and local government and utility support for building electrification has grown dramatically. In this section we discuss some of the significant policy and other developments that are leading to this increased interest and support.

### Utility GHG Goals

One important development in the last three years is the adoption of Colorado utility GHG emission reduction goals. **Figure 1** below shows that Colorado's six largest electric utilities or electricity-generating companies have committed to reduce their GHG emissions by at least 80% by 2030. These six utilities/generating companies provide 91% of Colorado's electricity. These impressive goals are partly in response to new state legislation affecting Colorado's electric utilities,<sup>8</sup> and partly due to public pressure resulting from increasing concerns about the impacts of climate change, as well as improving market conditions for renewable energy generation.

These GHG reduction goals provide the foundation for reducing GHG emissions through electrification of building fuel uses. The declining carbon-intensity of Colorado's electricity grid is

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<sup>6</sup> According to the U.S. EIA, gas prices will remain high during the 2022 winter months, and the 2022 average wholesale price will be about 35% higher than the average for the previous three years. See <https://www.worldoil.com/news/2021/10/18/eia-expects-us-natural-gas-prices-to-stay-high-through-the-winter>. Nobody knows what will happen to gas prices over the next 15 years, but we think it's likely they will remain significantly higher on average than over the past five years, due to higher liquid natural gas exports, stricter financial and environmental regulations, and continued bankruptcies of smaller gas producers.

<sup>7</sup> See for example, "Assessment of Natural Gas and Electric Decarbonization in State of Colorado Residential Sector," Black Hills Energy and GTI, March 2021.

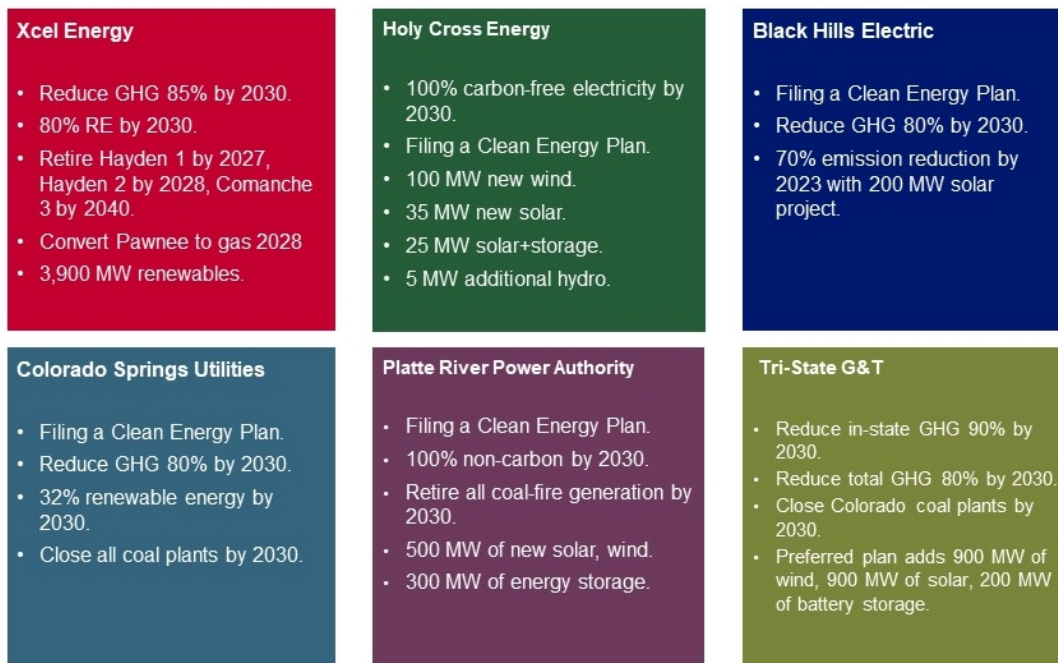
<sup>8</sup> See HB 19-1261, <https://leg.colorado.gov/bills/hb19-1261>, and HB 1266: [https://leg.colorado.gov/sites/default/files/2021a\\_1266\\_signed.pdf](https://leg.colorado.gov/sites/default/files/2021a_1266_signed.pdf).

incorporated into our assumptions of electricity emission rates, discussed below, and our findings regarding the GHG emissions benefits of heat pumps and HPWHs.

## State Goals and New State Policies

In 2019, the state passed House Bill (HB) 19-1261, which sets goals for state-wide GHG emission reductions of 26% by 2025, 50% by 2030, and 90% by 2050, from a 2005 baseline. Based on this law, the state developed a “GHG Pollution Reduction Roadmap,” which lays out near-term actions to achieve Colorado's emissions goals and includes specific targets for the various sectors of the economy. Fuel use in commercial and residential buildings accounts for 9.6% of Colorado’s total GHG emissions (6.3% for residential and 3.3% for commercial).<sup>9</sup> Within residential buildings, about 75% of the fuel use emissions are from space heating, most of the rest is from water heating, and a small amount is from cooking and gas fireplaces.

**Figure 1: Colorado Utility GHG Emission Reduction Goals**



For residential buildings, based on the Colorado GHG Roadmap, the Beneficial Electrification League of Colorado (BEL-CO)<sup>10</sup> developed the following goals for market penetration rates of heat pumps and HPWHs by 2030:

- 70% or more of all new or replacement central air conditioning (AC) units in existing homes are heat pumps.
- 70% or more of all propane furnace replacements in existing homes are heat pumps.
- 50% or more of all water heater replacements in existing homes are HPWHs.

<sup>9</sup> “2021 Colorado GHG Inventory Report,” Colorado Department of Public Health and Environment, 2021, [https://drive.google.com/file/d/1SFtUongwCdZvZEEKC\\_VEorHky267x\\_np/view](https://drive.google.com/file/d/1SFtUongwCdZvZEEKC_VEorHky267x_np/view).

<sup>10</sup> BEL-CO is a coalition of stakeholders in Colorado working to advance beneficial electrification in Colorado’s buildings and industrial facilities. BEL-CO members include Xcel Energy, Tri-State Generation and Transmission Association, Holy Cross Energy, Platte River Power Authority, the Colorado Energy Office, SWEEP, the Energy Efficiency Business Coalition, and several local governments and environmental groups.

- 80% or more of all new homes have heat pumps and HPWHs.

These are ambitious targets that will be challenging to achieve, but feasible with continued advances in heat pump technology, as well as strong incentives and other policy and program support.

In 2021, two new significant pieces of legislation were passed affecting building electrification. The first is Senate Bill (SB) 21-246, the “Beneficial Electrification” bill. This new law requires the state’s two regulated electric utilities to develop beneficial electrification (BE) plans for their residential, commercial, and industrial customers (not including transportation electrification). These BE plans must be submitted to the PUC for approval every three years, with the first plan due by July 1, 2022.<sup>11</sup> The utilities’ plans will likely result in increased rebates and other programs to promote heat pumps and HPWHs in residential and commercial buildings, additional training for contractors, and eventually programs for BE in industrial applications. The legislation also requires utilities to propose – and the PUC to approve – longer term targets for each utility’s BE efforts.

The second significant new law passed in 2021 is SB21-264, the “Clean Heat” bill. This law requires the state’s regulated gas utilities to develop “clean heat” plans to reduce their GHG emissions through a combination of:

- Reducing methane leaks from their distribution systems.
- Helping customers improve energy efficiency.
- Accelerating building electrification.
- Selling renewable gas or methane recovered from coal mines.

The regulated gas utilities must achieve goals of reducing their GHG emissions by 22% by 2030, from a 2015 baseline, with not more than 5% of the reductions coming from recovered methane or bio-methane.

Together, these new laws will encourage/require electric and gas utilities to help the state achieve its climate goals for the buildings sector. Many of the state’s electric utilities already have significant rebates and other programs to encourage building electrification, which we discuss below (after the Findings section).

## IMPROVEMENTS IN TECHNOLOGY

Over the past five years or so, there have been many successful installations of “cold-climate” heat pumps (defined in the next section), demonstrating their ability to provide efficient heating in cold climates. In addition, the Department of Energy (DOE), manufacturers, and other organizations are collaborating and sharing information to continue to improve the performance and cost-effectiveness of air-source heat pumps, including cold-climate heat pumps. For example, the [Advanced Heat Pump Coalition](#) has three subgroups that focus on: a) improved testing procedure and heat pump performance ratings, b) equipment roadmap and utility program needs, and c) design and installation best practices. In this report, we are focusing on air-source heat pumps.

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<sup>11</sup> The BE plans must support all cost-effective electrification, including the full social cost of carbon and methane emissions in cost-effectiveness evaluations; the plans cover new construction and existing buildings; and 20% of the funds must go to low-income households or disproportionately impacted communities.

Ground-source heat pumps make sense in some applications such as commercial or perhaps multi-family buildings but are much more expensive.<sup>12</sup>

HPWH technology also continues to improve. Several manufacturers now produce HPWH models that are “grid-enabled” or in other words, they can be controlled by the electric utility to reduce electrical demand during the utility’s peak periods.<sup>13</sup> In addition, three manufacturers are now producing, or will soon produce, HPWH models that run on 120 volt (V) circuits rather than requiring 240V, opening the door to much wider adoption.<sup>14</sup> Previously, homeowners considering replacing a gas water heater with a HPWH faced the obstacle of a potential electrical panel upgrade to accommodate a 240V circuit, which can be expensive. By only requiring 120V, the new models will eliminate that hurdle. On the other hand, the new 120V HPWHs give up the “hybrid” or electric resistance mode of operation, which reduces the recovery time for providing hot water during periods of higher hot water demand.

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<sup>12</sup> Ground-source heat pumps are better able to maintain their heat output and efficiency at low outdoor temperatures and are better suited to serving hydronic heating systems.

<sup>13</sup> The Northwest Energy Efficiency Alliance (NEEA) maintains a list of “qualified” heat pump water heaters meeting its specifications, including grid-enabled, at this website: <https://neea.org/img/documents/HPWH-qualified-products-list.pdf>.

<sup>14</sup> “A New Generation of Heat-Pump Water Heaters is on the Way,” Green Building Advisor, <https://www.greenbuildingadvisor.com/article/a-new-generation-of-heat-pump-water-heaters-is-on-the-way>.



# KEY ASSUMPTIONS

In this section, we summarize the scenarios we chose for the heat pump analysis, our equipment choices, and other key assumptions. More details are provided in the Appendix.

## LOCATIONS, SCENARIOS, AND EQUIPMENT CHOICES

### Cities

To provide a representative sample of the various electric and gas utility rates, we chose three cities for our analysis: Denver, Erie, and Pueblo. Denver is served by Xcel Energy for both electricity and gas. Erie is served by United Power (a rural electric cooperative) for electricity and by Black Hills Energy for gas. Most of Pueblo is served by Black Hills for electricity and by Xcel Energy for gas. By choosing these three cities, we highlight two different gas rates, and three different electricity rates. All three cities are in Climate Zone 5,<sup>15</sup> which covers the Front Range and much of the populous areas of Colorado. Choosing the same climate zone for all three cities also provides a more consistent basis for comparing heating energy consumption and costs.

### New Home Scenarios

For a new home in Climate Zone 5, we analyzed and modeled installing a cold-climate heat pump, sized properly, with no backup furnace. We consider this to be the preferred heat pump scenario for new homes in this climate zone. (However, we recognize that many developers may feel more comfortable installing heat pumps with a backup furnace, and we discuss this alternative scenario in the Appendix). For an average size single-family home, which we assume to be 2,000-2,500 square feet (ft<sup>2</sup>), the design or maximum heating demand (at an outside temperature of -1 degrees Fahrenheit (F) is about 36,000 Btu/hour.<sup>16</sup> In our analysis, we compare a properly-sized cold-climate heat pump with an efficient central AC system and a gas furnace. A cold-climate heat pump<sup>17</sup> will perform efficiently without a backup furnace down to the “design” outside temperatures (-1 degrees F for Denver and 0 degrees F for Pueblo).

### Retrofits to Existing Homes

For existing homes, SWEEP recommends starting with a home energy audit and making any needed efficiency improvements, including adding insulation, reducing infiltration, and sealing ducts, before installing a heat pump or replacing the gas furnace, to help reduce the home’s

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<sup>15</sup> For a map of climate zones in Colorado, see “Cold Climate Heat Pumps,” <https://loveelectric.org/heating-cooling/>.

<sup>16</sup> This is based on Manual J from ASHRAE, for an efficient new home, meeting ENERGY STAR 3.1 guidelines.

<sup>17</sup> According to the Northeast Energy Efficiency Partnerships’ (NEEP) criteria, cold-climate heat pumps have variable-capacity compressors and should achieve a coefficient of performance (COP) of at least 1.75 at 5 degrees F. Compared to standard heat pumps, cold-climate heat pumps achieve higher efficiencies over the whole range of outdoor temperatures. See <https://neep.org/heating-electrification/ccashp-specification-product-list>.

heating needs.<sup>18</sup> Adding solar PV will also further reduce the annual energy costs of adding a heat pump or HPWH to an existing home.

For heat pump retrofits, we assume the existing home has a maximum heating demand that is about 20% higher than for the average new home (mentioned above), because of less efficient initial construction. We compare replacing the central AC system (and gas furnace when necessary) with a new efficient ducted heat pump system with a backup gas furnace. The backup furnace for the heat pump system could be the existing furnace if it is in good condition and has a variable speed fan motor, or a new furnace if needed.<sup>19</sup>

For retrofits in Climate Zone 5, we analyzed an efficient, 2-speed heat pump, sized to provide heating down to ~20 degrees F, paired with an efficient backup furnace capable of handling the colder temperatures. The 2-stage heat pump will perform efficiently down to this changeover temperature (the temperature at which the heating system switches to relying on the furnace). It is also possible to install a cold-climate or 2-stage heat pump with no backup furnace, but doing so will increase the installed costs of the heat pump retrofit (with the cold-climate heat pump), or increase the annual heating costs (with the 2-stage heat pump) because the unit will rely more on electric resistance as a backup during the coldest temperatures. We expect the dual-fuel retrofit to be the most practical and common retrofit configuration for at least the next 5-7 years. However, a cold-climate heat pump can meet the home's full heating needs in this climate, and there may be cases where such an installation is preferable. We discuss alternate all-electric retrofit scenarios in the Appendix.<sup>20</sup>

For Denver, Erie, and Pueblo, choosing a "changeover temperature" of 20 degrees F will allow the heat pump to provide about 80% of the home's annual heating needs. A higher changeover temperature such as 30 degrees F would allow the gas furnace to provide 40-50% of the home's annual heating needs, which could help reduce the annual heating costs, but results in significantly greater GHG emissions than the 30 degree F changeover.

## Equipment Specifications and Installed Costs

Our equipment specifications are shown in **Table 1** below and explained further in the Appendix. Our goal is to compare an efficient heat pump system (with relatively low annual heating costs and reasonable installation costs) with an efficient gas furnace and central AC system. There are many possible configurations of ducted or ductless heat pumps. For this analysis we chose a simple system, involving a centrally ducted heat pump system, for both new homes and retrofits. **Table 1** also shows our estimates of the installed costs for our recommended new home scenario and the 80% heat pump dual-fuel retrofit scenario. For a 3-ton heat pump system, the incremental cost of

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<sup>18</sup> For more tips on these types of energy efficiency improvements, see "Insulation and Air Sealing," <https://loveelectric.org/heating-cooling/>.

<sup>19</sup> A variable-speed (electronically commutated motor or ECM) fan motor will dramatically improve the efficiency of the heating system, and most new furnaces made since ~2000 have one. Also note that we could have compared the new heat pump system (with existing furnace as a backup) with installing a new AC system but with the existing furnace used for all the heating needs. In this scenario, the heat pump has even more emissions and cost benefits compared to the existing, inefficient furnace. However, to be slightly conservative, we assume the furnace is replaced (with a 95% efficient one) at the time of the AC replacement, or within a few years.

<sup>20</sup> For additional retrofit scenarios, involving different existing heating systems, sizes of homes, and climate zones, see <https://loveelectric.org/heating-cooling/>. (On this page, scroll down to "Heat Pump Applications.")

the heat pump compared to the central AC system with a gas furnace, should be about \$3,200 for a new home (not including savings from avoiding gas lines to the home if it is all-electric), and about \$1,800 for an existing home. The reason the cost is higher for new homes is because cold-climate heat pumps are more expensive than 1- or 2-stage heat pumps.

**Table 1: Equipment Specifications and Installed Costs<sup>21</sup>**

Scenario	Heat Pump	Gas Furnace + Central AC <sup>22</sup>	
<b>Retrofit of existing home</b>	Ducted, 2-speed, HSPF 9.5+ (with 90% AFUE backup furnace <sup>23</sup> )	95% AFUE	SEER 16+
<b>Installed cost<sup>24</sup></b>	<b>\$14,800</b>	<b>\$13,000</b>	
<b>New home</b>	Ducted, cold-climate, HSPF 9.5+, (with electric strip backup)	95% AFUE	SEER 16+
<b>Installed cost</b>	<b>\$15,200</b>	<b>\$12,000</b>	
<b>Water heater - new or existing home</b>	HPWH - UEF of 3.3	Gas water heater - UEF of 0.68	
<b>Installed cost</b>	<b>\$2,800</b>	<b>\$1,900</b>	

## Heat Pump Water Heaters

HPWHs generally require a 240V, 40 Amp circuit. As mentioned above, several manufacturers are now producing models that only require a 120V circuit, with slightly reduced recovery rate. The 240V circuit requirement does not cause any issues for new homes, but for existing homes not set up for an electric water heater, this could require installation of a new circuit or a panel upgrade, which can be expensive. Finding a suitable location in an existing home, with enough space and ventilation, can be another potential challenge. The installed costs shown in **Table 1** are for 240V HPWHs, and assume that the existing home has a suitable location and does not require an electrical panel upgrade.<sup>25</sup>

<sup>21</sup> HSPF means Heating Seasonal Performance Factor. AFUE means Annual Fuel Utilization Efficiency. SEER means Seasonal Energy Efficiency Rating.

<sup>22</sup> In our analysis, we do not compare cooling costs, but we list the efficiency of the central AC system because this affects the initial cost assumptions.

<sup>23</sup> If the backup furnace needs to be replaced, we recommend the replacement should have a variable-speed/ECM motor and minimum efficiency of 90% AFUE.

<sup>24</sup> The installed costs for heat pumps and HPWHs are based on "Cost and Other Implications of Electrification Policies on Residential Construction," Research Innovation Research Labs and National Association of Home Builders, February 2021, see Appendices A and B. We adjusted a few of the estimated incremental costs based on input from knowledgeable local heat pump and HPWH contractors. Estimates of installed costs for heat pump systems compared to central AC and gas furnace systems vary quite a bit depending on the contractor's expertise and comfort with heat pumps and HPWHs.

<sup>25</sup> More details on HPWH performance and installation guidelines: <https://loveelectric.org/hot-water/>.

## Model of Heat Pump Performance

To analyze the heating performance of the heat pump system compared to the gas furnace, we used the Wright-Suite Universal 2021 HVAC modeling package. This model allows the user to choose specific manufacturers and specifications of heat pumps and uses their tested performance specifications to predict the efficiencies (COPs) at various temperatures, based on weather data for any specific city. More details on this model are provided in the Appendix.

## ELECTRICITY AND GAS RATES, AND LIFE-CYCLE COSTS

To compare the lifecycle costs of heat pumps vs. gas furnaces from the consumer perspective, we used the most recent volumetric electricity and gas rates for the utilities serving the three cities chosen. (The volumetric rates are the per kWh or per therm components of the monthly rates.) We provide these in **Table 2** below. Gas rates have increased significantly since our 2018 report. The result of the higher gas prices is that the difference in annual heating costs between gas systems and heat pump systems is now very small (shown in the Findings section below).

**Table 2: Electricity and Gas Rates**

City	Electric Utility	Electricity Rate (\$/kWh)	Gas Utility	Gas Rate (\$/therm) <sup>26</sup>
Denver	Xcel Energy	\$0.1082/\$.0973 <sup>27</sup>	Xcel Energy	\$0.8130
Erie	United Power	\$0.1000	Black Hills	\$0.7632
Pueblo	Black Hills	\$.01499/\$0.1799 <sup>28</sup>	Xcel Energy	\$0.8130

In our analysis, we compared the life-cycle costs for the above scenarios, over a 15-year life of the equipment for the heat pump.<sup>29</sup> The life-cycle costs include the initial installed costs of the equipment, and the net present value of the 15-year fuel costs for heating. (We used a 12-year life for the water heater comparison.)

Finally, based on the GHG emissions benefits, we also included the social cost of carbon (SCC) (including methane) in the life-cycle analysis. For the value of the social cost of carbon, we used \$83/metric ton CO<sub>2</sub>e, from the most recent federal update.<sup>30</sup> The purpose of including the social cost of carbon and methane is to account for additional benefits associated with the heat pump,

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<sup>26</sup> These are based on November 2021 gas rates, and we assumed a modest annual price escalation in addition to inflation (0.5%). We also used a 0.5% annual escalation rate for electricity prices.

<sup>27</sup> These are the time-of-use (TOU) rates that would apply to heat pumps/HPWHs. For heat pumps, we used all hours during the heating season. For HPWHs, we assumed avoiding operating during the peak rate hours (3-7pm weekdays).

<sup>28</sup> The lower rate applies to the first 500 kWh per month; the higher rate is for usage over 500 kWh. For heat pumps, we assume 25% of the heat pump's consumption is at the lower rate above, and 75% of consumption is at the higher (over 500 kWh/month) rate. For HPWHs, we assume the lower rate applies.

<sup>29</sup> A heat pump or central AC system has an expected life of 15-18 years. We chose 15 years to be slightly conservative about the expected life of heat pump systems.

<sup>30</sup> 2025 value based on a discount rate of 2.5%. "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide," U.S. Government Interagency Working Group, February 2021, [https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument\\_SocialCostofCarbonMethaneNitrousOxide.pdf](https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf).

and to help determine what level of utility rebates for the heat pump can be justified to help it be cost neutral compared with the conventional heating systems. Colorado law now requires the inclusion of the social cost of carbon and methane in utility resource planning as well as in the analysis of BE program cost effectiveness.<sup>31</sup>

## GHG EMISSIONS

There are two possible types of electricity GHG emission factors one could use to compare the benefits of heat pumps: annual average emission factors, and marginal emission factors. The latter is the most appropriate for comparing the societal benefits of programs to encourage more adoption of heat pumps and HPWHs.<sup>32</sup> However, it is much more complicated to model and project these marginal emission factors over a 15-year period (which is the main reason we did not take this approach in SWEEP's 2018 heat pump report).

Fortunately, the National Renewable Energy Laboratory (NREL) has developed a model and has calculated these emission factors, for all states, for 15-year periods such as 2022-37. For Colorado, NREL's marginal 15-year GHG emission factor for this time period is 600 lb CO<sub>2</sub>/MWh,<sup>33</sup> and we used this emission factor in our calculations of the GHG emission benefits of heat pumps and HPWHs, summarized below. In the Appendix, we explain some of the main assumptions and methodologies involved in NREL's model. NREL's model accounts for the most recent CO<sub>2</sub> emission reduction commitments by Colorado's electric utilities.

In addition to analyzing the GHG emissions from electricity consumption by heat pumps and HPWHs compared to the end-use combustion of gas in furnaces or water heaters, we also estimate the methane emissions from leaks in the gas distribution system and in the home's gas meter and equipment.<sup>34</sup> Based on various studies, estimates of these emissions range from a total leakage rate of 0.3% to 1.0%, and for our analysis, we assumed the total methane leakage rate from the gas distribution system through the home's equipment to be 0.8%.<sup>35</sup> We think this is a

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<sup>31</sup> "Electric Utility Promote Beneficial Electrification," Colo. Senate Bill 21-246, <https://leg.colorado.gov/bills/sb21-246>.

<sup>32</sup> Briefly, the marginal emission factors are based on the generating resources that are "on the margin" – in other words, those used to ramp up and down to meet a utility's changing load conditions. Using marginal emission factors would help answer the question, "What are the emissions benefits of new policies/programs to encourage more heat pumps?"

<sup>33</sup> The annual long-range marginal emission rates for states can be found at "Cambium data for 2021 Standard Scenarios," National Renewable Energy Laboratory, <https://cambium.nrel.gov/?project=a3e2f719-dd5a-4c3e-9bbf-f24fef563f45&mode=download&layout=Default>.

<sup>34</sup> Note that this does not include the upstream methane emissions from gas production and transmission to the gas utility or to gas-fired electricity generating plants. Including estimates of upstream methane emissions would increase the GHG emissions benefits associated with heat pumps compared to gas heating systems. However, we are excluding the upstream methane emissions for two reasons: a) the Clean Heat bill requires the gas utilities to reduce emissions from leakage on their distribution systems and from consumption of fuels by their end-use customers' they do not need to account for or take responsibility for upstream methane leakage; b) There is a great deal of uncertainty in estimates of upstream methane leakage rates, which would cloud our comparisons of GHG emissions from heat pumps/HPWHs vs. gas heating.

<sup>35</sup> Denver assumed a leakage rate over the gas distribution system to be 0.3%. The California Energy Commission found a total leakage rate in the customer's home, from the meter, incomplete combustion, and pilots to be 0.5%. M. Fischer, et al, "Gas Methane Emissions from California Homes," California Energy Commission, Sacramento, 2018.

reasonable and slightly conservative estimate of these methane emissions. Finally, we used the most current 100-year global warming potential for methane, which is 28.<sup>36</sup>

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<sup>36</sup> “Climate Change 2014: Synthesis Report,” Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, <https://bit.ly/3358dxo>, p. 87. We chose the 100-year GWP to be consistent with the federal and Colorado requirements for calculating the social cost of carbon.

# FINDINGS

Our findings show that heat pumps have higher life-cycle costs than the gas heating alternatives (without including utility, local government, or federal rebates), but the annual heating costs are very close – within about 10% (except for homes in Pueblo, due to Black Hills Energy’s higher electricity rates). Our analysis also shows that the GHG emissions benefits of heat pumps versus gas heating are significant. Adding the social cost of carbon and methane to the life-cycle costs shows that heat pumps are very close in total life-cycle costs compared to gas heating from a societal cost perspective, again except for homes in Pueblo. And from a societal cost perspective, HPWHs are also very close in life-cycle costs to gas water heaters. (We discuss utility and federal rebates in the next section and in the summary section.)

## HEAT PUMPS

**Table 3** below shows our comparison of annual heating costs for new homes and for existing homes with heat pump retrofits.<sup>37</sup> For Denver and Erie, the heating costs are slightly higher for the heat pump scenarios, but are within about \$80 per year, or an average of only about \$7/month. For Pueblo, the heating costs are significantly higher for the heat pump scenarios because of Black Hills Energy’s high electricity rates.

**Table 3: Annual Heating Costs**

City and Scenario	Gas Furnace			Heat Pump and Gas Furnace		
	Gas Use (therms)	Electricity Use (kWh)	Annual Heating Costs (\$)	Gas Use (therms)	Electricity Consumption (kWh)	Annual Heating Costs (\$)
<b>New home</b>						
Denver	769	572	\$687	0	7106	\$769
Erie	769	572	\$644	0	7106	\$711
Pueblo	745	560	\$690	0	6922	\$1,193
<b>Retrofit of existing home</b>						
Denver	947	710	\$847	155	7381	\$924
Erie	947	710	\$794	155	7381	\$856
Pueblo	930	697	\$860	177	7041	\$1,358

Note: For heat pump scenarios, the new home has a cold-climate heat pump with no backup furnace, and for the retrofit the data shown is for the 20F changeover scenario, in which the heat pump provides about 80% of the annual heating needs.

<sup>37</sup> We did not analyze cooling costs, but it’s also somewhat likely that an efficient heat pump (with a heating efficiency of HSPF 9.0+) will also reduce the home’s cooling costs compared to a 16 SEER AC system.

**Table 4** summarizes the GHG emissions benefits of heat pumps vs. gas furnaces. Again, for the retrofit scenario, we are assuming the 20 F changeover temperature. As shown, the total GHG emission reductions with heat pumps compared to gas furnaces are about 49% for new homes, and 40-41% for existing homes. These are average values over the 15-year period, from 2022-37, based on the projected significant reductions in carbon intensity of Colorado’s electricity grid over this period. We explain this further in the next section, as well as in the Appendix. (A home with a rooftop solar PV system will have even lower GHG emissions from heating and cooling.)

**Table 4: GHG Emissions Comparison**

City and Scenario	Gas Furnace		Heat Pump with Backup Gas Furnace		Percentage Emission Reductions for Heat Pump, incl. Methane
	GHG Emissions (lb CO2/yr)	GHG Emissions Including Methane Leakage (lb CO2e/yr)	GHG Emissions (lb CO2/yr)	GHG Emissions Including Methane Leakage (lb CO2e/yr)	
<b>New home</b>					
Denver	9,335	10,142	4,255	4,255	58.0%
Erie	9,335	10,142	4,255	4,255	58.0%
Pueblo	9,054	9,836	4,145	4,145	57.9%
<b>Retrofit of existing home</b>					
Denver	11,503	12,497	6,233	6,396	48.8%
Erie	11,503	12,497	6,233	6,396	48.8%
Pueblo	11,295	12,271	6,288	6,474	47.2%

As mentioned above, installed costs for cold-climate heat pumps are higher than for 2-stage heat pumps, and we estimate the incremental life-cycle costs for the heat pump scenarios to be about \$3,200 for a new home and about \$2,000 for retrofits. **Table 5** provides a summary of the life-cycle heating costs and total incremental life-cycle costs for the heat pump compared to the gas furnace system. Note that because of the uncertainty in gas prices over the next 15 years, there is a fair amount of uncertainty in the difference in the life-cycle fuel costs shown. (We know that gas prices will continue to be much more volatile than electricity prices, but we don’t know whether or how much they will increase relative to electricity prices over this period.)

We also show the net present value of the GHG emission reductions using the social cost of carbon and methane, which is about \$2,300 for both new and existing homes. This means that utility or local government rebates of up to ~\$2,300 would be justified from a societal perspective, and as shown, this amount of rebates would offset almost all of the customer’s additional life-cycle costs for existing homes, except for homes in Pueblo. For new homes, \$2,300 will offset about 60% of the incremental life-cycle costs of cold-climate heat pumps. However, in an all-electric new home, the avoided cost of the gas line to the home will more than offset the rest of the incremental costs for the heat pump.

In the last section below, we discuss the proposed federal rebates available for heat pumps, and SWEEP’s suggestions for Colorado utility rebates.



**Table 5: Life-Cycle Costs for Heat Pumps**

City and Scenario	Gas Furnace	Heat Pump	Difference in Installed Cost for Heat Pump System vs. Gas Furnace	Total Incremental Life-Cycle Costs for Heat Pump (\$)	Total NPV of GHG Emission Benefits (\$) (using social cost of carbon and methane)
	NPV of Heating Costs (\$)	NPV of Heating Costs (\$)			
<b>New home</b>					
Denver	\$7,387	\$8,266	\$3,200	\$4,079	<b>\$2,300</b>
Erie	\$6,925	\$7,642	\$3,200	\$3,918	<b>\$2,300</b>
Pueblo	\$7,554	\$12,834	\$3,200	\$8,480	<b>\$2,224</b>
<b>Retrofit of existing home</b>					
Denver	\$9,105	\$9,942	\$1,800	\$2,637	<b>\$2,383</b>
Erie	\$8,535	\$9,211	\$1,800	\$2,476	<b>\$2,383</b>
Pueblo	\$9,422	\$14,409	\$1,800	\$6,787	<b>\$2,265</b>

Notes: Cold climate heat pump (no furnace) for new homes, 2-stage heat pump with backup furnace for existing home. Also note that for an all-electric new home, the avoided cost of the gas piping to the home will also help offset the incremental costs for the heat pump and HPWH.

## HEAT PUMP WATER HEATERS

**Table 6** summarizes the annual energy costs for HPWHs compared to gas water heaters and shows that HPWHs cost \$20-30 per year less than gas water heaters for homes in Denver and Erie. We also included standard electric water heaters to this comparison. **Table 7** compares the GHG emissions benefits, which are significant for HPWHs.

**Table 8** shows the life-cycle costs of HPWHs. Without the social cost of carbon and methane, the life-cycle cost of the HPWH is \$500-600 greater than a gas water heater in Denver and Erie, and about \$900 higher in Pueblo. But with valuation of the social cost of carbon and methane, the HPWH has a slightly lower lifecycle cost in Denver, about the same cost in Erie, and about a \$300 greater life-cycle cost in Pueblo.

**Table 6: Annual Costs for Water Heaters**

City	HPWH Cons. (kWh/yr)	HPWH Annual Costs (\$)	Std Electric Water Heater Cons. (kWh/yr)	Std. Electric Annual costs (\$)	Gas Water Heater Cons. (MMBtu/yr)	Gas WH Annual Costs (\$)
Denver	892	\$87	3,100	\$302	14.78	\$120
Erie	892	\$89	3,100	\$310	14.78	\$113
Pueblo	892	\$134	3,100	\$465	14.78	\$120

**Table 7: GHG Emissions of Water Heaters**

City	HPWH		Standard Electric WH		Gas WH		Percent Reduction for HPWH compared to Gas WH
	Cons. (kWh/yr)	GHG Emissions (lb CO2/yr)	Cons. (kWh/yr)	GHG Emissions (lb CO2/yr)	Cons. (MMBtu/yr)	GHG Emissions including Methane Leakage (lb CO2e/yr)	
All cities	892	595	3,100	1,846	15	1,884	68.4%

**Table 8: Life-cycle Costs for Water Heaters**

City and Scenario	Gas Water Heater	HPWH	Difference in installed cost for HPWH vs. gas WH	Total incremental life-cycle costs for HPWH (\$)	Total value of GHG emission benefits (\$) (using social cost of carbon and methane)
	NPV of heating costs (\$)	NPV of heating costs (\$)			
<b>New homes or replacements of water heaters in existing home<sup>38</sup></b>					
Denver	\$1,103	\$798	\$900	\$594	\$409
Erie	\$1,036	\$820	\$900	\$684	\$409
Pueblo	\$1,103	\$1,229	\$900	\$1,025	\$409

Note: For this comparison, we assumed a 12-year life (the expected life of a typical water heater).

## ALL-ELECTRIC NEW HOMES

There are many benefits from all-electric new homes. For the homeowner, all-electric new homes should cost about the same as a new home with gas heating for space and hot water. New home developers benefit from avoiding the gas piping to the new home, which amounts to \$4,000-5,000 per home, as shown in **Table 9**. For the homeowner, not having any gas service avoids all the monthly fixed costs from the gas utility, and these add up to more than \$150 per year, more than offsetting the slightly increased annual heating costs for the heat pump (except for Pueblo homes). These cost benefits are summarized in **Table 8**. Note that even with slightly higher initial costs for the heat pump and induction cooktop/range, the all-electric home has lower total life-cycle costs. (We also recognize that for some new home developers, installing heat pumps with a backup gas furnace, rather than central AC systems with furnaces, may be a helpful first step before they feel comfortable with all-electric developments.)

<sup>38</sup> For existing homes, the incremental cost of \$900 assumes that the home does not require an upgrade to the electrical panel, or any additional ducting from the water heater (e.g., to a hallway or adjacent room).

In addition, electric cooking provides significant health and safety benefits. Several studies have found that nitrogen oxide emissions from cooking with gas leads to increased asthma in children.<sup>39</sup> A recent study also found that there is significant methane leakage from gas stoves, even when they are not being used.<sup>40</sup> Electric cooking and heating also reduces risks of explosions from gas leaks and from potential carbon monoxide poisoning.

On top of these benefits, induction cooking offers better performance than cooking with gas.<sup>41</sup> On the other hand, induction cooktops/ranges cost more than their conventional electric (with radiant cooktops) or gas counterparts and may require purchasing some new cookware – induction cooking requires pots and pans with magnetic properties (iron or steel).

Note that for new homebuyers that really want a gas fireplace, they could choose an electric one instead, which still offers warmth and esthetic beauty, but without any actual flames or emissions. And another option for a backup or supplemental heating source is to install an efficient wood pellet stove.

**Table 9: All-Electric New Home Cost Comparison<sup>42</sup>**

<b>HVAC Costs</b>	<b>95% Efficient Gas Furnace and AC</b>	<b>Cold-Climate HP with Electric Strip</b>
Initial cost excluding ducts	\$12,000	\$15,200
Rebates	\$800	\$1,000
Total cost after rebates	\$11,200	\$14,200
Annual heating costs	\$687	\$769
<b>Water Heater Cost</b>	<b>ENERGY STAR Gas Water Heater (50 gal)</b>	<b>ENERGY STAR HPWH (50 gal)</b>
Installed cost	\$1,900	\$2,800
Rebate	\$50	\$800
Total cost after rebates	\$1,850	\$2,000
Annual heating costs	\$120	\$87
<b>Infrastructure Costs</b>	<b>Gas</b>	<b>Electric</b>
Electrical modification to go all-electric	\$0	\$700
External gas piping for the development (per home)	\$2,500 <sup>43</sup>	0

<sup>39</sup> "Gas Stoves: Health and Air Quality Impacts and Solutions," RMI, Physicians for Social Responsibility, 2020, <https://rmi.org/insight/gas-stoves-pollution-health>.

<sup>40</sup> Eric D. Lebel, Colin J. Finnegan, Zutao Ouyang and Robert B. Jackson, Methane and NO<sub>x</sub> Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes, Environmental Science & Technology, January 2022, <https://pubs.acs.org/doi/10.1021/acs.est.1c04707>.

<sup>41</sup> For example, see the short videos provided here: <https://loveelectric.org/cooking/>.

<sup>42</sup> We used gas and electricity rates and rebates from Xcel Energy for this comparison.

<sup>43</sup> This estimate is based on conversations with several new home developers and utilities.

Gas meter and utility hookup charge, and internal gas piping for 3.5 gas appliances	\$2,300	0
Cooktop/range costs	Gas range	Induction/electric range
Initial cost	\$1,800	\$2,900
<b>Total equipment/infrastructure costs</b>	<b>\$19,650</b>	<b>\$18,800</b>
Fixed natural gas charges (on monthly bills)	\$173	
Total annual heating costs (not including cooking)	\$980	\$855
<b>NPV of heating costs - 15 years</b>	<b>\$10,477</b>	<b>\$9,200</b>
<b>Total NPV of costs</b>	<b>\$30,127</b>	<b>\$28,000</b>

# COLORADO UTILITY PROGRAMS

Most Colorado utilities already provide rebates for heat pumps and HPWHs. And several utilities are collaborating to improve their training programs for heat pump installers, an important obstacle to overcome if we want to see an increased number of reasonably-priced heat pump installations, properly installed to achieve efficient operation and to avoid problems.

## CURRENT UTILITY REBATES

Based on our recent surveys, 40 out of 52 Colorado electric utilities provide rebates for heat pumps and HPWHs. For heat pumps, these range from \$500 for ducted or mini-split heat pumps offered by Platte River Power Authority's member municipal utilities, to the most generous rebate by a Colorado utility: \$850/ton for a cold-climate heat pump, offered by Holy Cross Energy.<sup>44</sup> Xcel Energy offers \$800 for most heat pumps, and most of Tri-State's member co-ops offer heat pump rebates of \$450/ton. A typical rebate for HPWHs is \$400-500. In addition, many local governments and non-profit organizations (e.g., City of Boulder and the Community Office for Resource Efficiency in the Roaring Fork Valley) offer rebates on top of the utilities' rebates. All Colorado utility and local government rebates for heat pumps and HPWHs are listed on the Love Electric website.<sup>45</sup>

In addition to Colorado rebates, the climate provisions included in the proposed Build Back Better Act include new federal rebates and tax incentives for heat pumps and HPWHs. These include rebates of up to \$3,000 for ordinary heat pumps, \$4,000 for cold climate heat pumps, \$1,250 for HPWHs, and \$3,000 for service panel upgrades, if necessary, for homes in general. The rebate is up to 50% of installed cost with a maximum total incentive of \$10,000 per home. Higher rebate amounts are possible for qualifying low and moderate-income households, including allowing incentives up to 100% of installed cost. The exact amount of the rebates will be determined by the DOE.

## UTILITY COLLABORATIONS ON TRAINING AND REBATES

Contractor training continues to be an obstacle for further heat pump adoption. When HVAC contractors are not comfortable with heat pumps, they tend to overprice them, and/or recommend the more traditional approaches to heating and cooling.

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<sup>44</sup> Holy Cross offers this level of rebate for cold-climate heat pumps replacing a fuel (gas or propane) rather than electric resistance heating, and the heat pump must be used "80% of the time as the primary source of heating." See <https://www.holycross.com/residential-rebates/>.

<sup>45</sup> See <https://loveelectric.org/rebates/>. On this page, start by clicking on the specific utility (e.g., Xcel Energy), and then the utility rebate page will also indicate local government rebates that may also apply.

BEL-CO, several Colorado utilities, the Energy Efficiency Business Coalition, SWEEP, and the Colorado Energy Office have been collaborating on training programs for heat pump installers/contractors. These efforts so far have included:

- Xcel Energy has shared information about its comprehensive “quality installation” (QI) training program for AC and heat pump installers and has opened this training to contractors outside its service territory.
- Tri-State and PRPA have also shared information about their respective QI training programs.
- All the above organizations are meeting quarterly with many of the state’s leading heat pump distributors to discuss how to build support and remove obstacles to more heat pump sales.

# SUMMARY AND RECOMMENDATIONS

Heat pumps have much lower annual heating costs compared to propane or electric resistance heating. Many utilities already target these types of heating systems for heat pump retrofits. In this report, we compare several options for heat pumps versus gas heating, in both new homes and existing homes in Colorado, focusing on three cities in the Front Range/Climate Zone 5, each served by different utilities. Compared to SWEEP's 2018 residential heat pump study, heat pumps and HPWHs are now more cost-effective, mainly due to the recent significant increase in gas prices, which we expect to continue.

Heat pump technology continues to improve, and more manufacturers are producing highly efficient models, including cold-climate heat pumps. For homes heated with gas, many heat pump manufacturers, distributors, and contractors agree that replacing central AC systems with a heat pump system to provide cooling while also offsetting some/most of the home's heating needs is a relatively easy first step toward greater heat pump adoption. However, lack of adequate contractor training continues to be an obstacle. When HVAC contractors are not comfortable with heat pumps, they tend to overprice them, and/or recommend the more traditional approaches to heating and cooling.

Most of Colorado's electric utilities are now offering rebates for heat pumps and HPWHs and coordinating to create better contractor/installer training. By focusing on the most cost-effective applications and continuing to collaborate on contractor training and other outreach efforts, the state can achieve its heat pump market development goals (summarized above). The most cost-effective heat pump and HPWH applications include:

- Full or partial replacements of propane and electric resistance heating systems with heat pumps in existing homes.
- In homes with gas heating, replacements of central AC systems with efficient hybrid heat pump systems (heat pump with backup furnace).
- In new homes, cold-climate heat pumps with no backup furnace in all-electric new homes.
- HPWHs in new homes.
- HPWHs in existing homes, when there is a suitable location and adequate space, and when an electrical panel upgrade is not required.

In addition, new state policies will help drive further increases in heat pump rebates and improvements in heat pump installer training programs. In addition to utility and local government rebates, the federal government may begin providing substantial rebates for heat pumps if the climate portions of the Build Back Better Act are approved by the Congress and signed into law by President Biden. The combined utility and federal rebates (if these portions of the bill pass) will allow homeowners to save money over the life of the heat pump or HPWH, while also significantly reducing their carbon footprint.

Here is a summary of our main findings:

## COSTS AND GHG EMISSIONS

- With current gas prices, the annual heating costs for heat pumps are within about 10% (or about \$80/year) of costs for the gas heating alternatives, based on our scenarios and key assumptions.
- HPWHs have lower annual energy costs than gas water heaters.
- Because of the steadily declining carbon intensity of Colorado's electricity grid, heat pumps and HPWHs reduce GHG emissions significantly (by about 55% for heat pumps, and 68% for HPWHs) compared to the gas heating alternatives.

## GENERAL RECOMMENDATIONS

- For new homes in Climate Zone 5, we recommend that developers and builders install cold-climate heat pumps without a backup furnace.
- For retrofits of homes with central AC and a gas furnace, we recommend replacing the AC system with an efficient 2-speed heat pump, and keeping (or replacing as needed) the furnace to heat the home for outside temperatures below ~20 degrees F. This will allow the heat pump to provide about 80% of the home's annual heating needs.
- For retrofits, the 80% gas displacement scenario is a potential steppingstone to full electrification of home heating when the gas furnace and/or heat pump needs to be replaced in 15 years or so, at which time a cold-climate heat pump replacement will be more cost-effective. For homeowners who would like to completely eliminate their gas heating today, there are options for doing so, but the installation costs or annual heating costs will be significantly higher than for the ~80% gas displacement scenario. However, there may be certain cases where all-electric retrofits are warranted, such as to help avoid expanded gas piping infrastructure to serve a specific area.

## RECOMMENDATIONS FOR UTILITY PROGRAMS

- Electric utilities should provide strong incentives for heat pumps for both existing and new homes, and for HPWHs, taking into account the social cost of carbon and methane. SWEEP's suggested rebates and minimum specifications for heat pumps and HPWHs are summarized below in **Table 10**. There are many brands and models of heat pumps and HPWHs that meet these specifications.
- If the climate provisions of the Build Back Better Act are not approved, we suggest that utilities consider even higher rebates, e.g. \$3,000, for a cold-climate heat pump, to help accelerate the adoption of these technologies.
- For new homes, we encourage utility programs to offer rebates for cold-climate heat pumps (with no backup furnace), and additional incentives for all-electric new homes, to help avoid new gas infrastructure for new home developments.
- For existing homes, we encourage utility programs to emphasize replacements of central AC systems with efficient heat pumps. To support this strategy, utilities should significantly reduce their rebates for central AC systems while offering larger incentives for heat pumps.
- Utilities should continue to support and collaborate on heat pump and HPWH contractor training programs, such as through the BEL-CO subgroup on this topic.



**Table 10: Model Utility Heat Pump and HPWH Rebates**

Heat Pump	Rebate Amount	Minimum Specifications
1-2 ton heat pump	\$700	HSPF 10+
Non-cold climate heat pump, 3 tons or greater	\$1,800	HSPF 9.0+, SEER 16+, 1- or 2-stage compressor <sup>46</sup>
Cold-climate heat pump, 3 tons or greater <sup>47</sup>	\$2,400 <sup>48</sup>	a) multi-stage (3 or more) or continuously variable compressor; b) HSPF 9.5+/10.0+ (ducted/ductless); c) COP 1.75+ at 5 degrees F, and/or listed on NEEP's qualified cold-climate product list, d) SEER 16+
HPWHs <sup>49</sup>		
Non-grid connected	\$750	UEF 3.2+
Grid-connected	\$1,000	UEF 3.2+

## RECOMMENDATIONS FOR THE COLORADO PUC

- Consider requiring Black Hills Energy to offer a time-of-use (TOU) rate. TOU rates such as Xcel Energy's help support heat pumps and HPWHs by: a) offering lower rates during the non-peak (heating season) months; and b) offering lower daily off-peak rates, which HPWHs can take advantage of by avoiding the on-peak usage periods.
- Encourage gas utilities to provide additional incentives for heat pump retrofits (in addition to those provided by the electric utilities), and for weatherization and other efficiency improvements to homes getting these retrofits.
- To help avoid gas piping infrastructure to serve new developments, encourage electric utilities to offer higher rebates for all-electric new homes.
- To help avoid expanded gas piping infrastructure to serve existing areas, encourage electric and gas utilities to offer significantly higher rebates for all-electric, cold-climate heat pump retrofits of homes in these areas.

<sup>46</sup> For retrofits, we suggest an efficient 1- or 2-stage, non-cold climate heat pump, which will allow the heat pump to displace up to 80% of the home's gas usage.

<sup>47</sup> We suggest cold-climate heat pumps for new construction or all-electric retrofits in climate zones 5 or higher. These cold-climate heat pump specifications are based on NEEP's specification, with two minor changes: a) HSPF 9.5+ for ducted, instead of NEEP's minimum of 9.0+; and b) SEER 16+, instead of NEEP's minimum of 15. Many models of heat pumps meet these minimum specifications, including 80-90% of those listed on NEEP's qualified product list, which can be found here: <https://neep.org/heating-electrification/ccashp-specification-product-list>.

<sup>48</sup> Based on our calculations, the value of the GHG emissions benefits of a cold-climate heat pump in a new home over a 15-year period is about \$2,300, which we rounded up to \$2,400.

<sup>49</sup> These rebate levels are consistent with Xcel Energy's current rebates. On specifications, NEEA has a list of "qualified" heat pump water heaters here, almost all of which achieve the minimum UEF shown above: <https://neea.org/img/documents/HPWH-qualified-products-list.pdf>.

## RECOMMENDATIONS FOR BUILDING CODES AND RELATED LOCAL POLICIES

- Local jurisdictions should review their permitting criteria to make sure replacing a gas furnace with an electric heat pump is at least as quick and easy as replacement with another gas unit.
- Local jurisdictions should consider prioritized permit review, reduced permit fees, and/or increased density bonuses for new all-electric buildings or new heat pump systems.
- In the near term, SWEEP urges state and local governments to adopt the latest version of the International Energy Conservation Code (IECC), along with electric-ready (i.e., including electric appliance wiring), electric-preferred (i.e., requiring stronger efficiency for non-electric appliances to offset the additional emissions), or all-electric code requirements.
- In the medium term (i.e., by 2030), we recommend that cities and counties adopt a near-zero carbon code requiring new homes to contain either: a) an efficient heat pump system and other high efficiency electric appliances; or b) a mix of high efficiency electric and gas equipment but with additional energy efficiency and/or renewable energy features, so that the mixed fuel use home does not result in higher carbon emissions than an efficient all-electric home.

# APPENDIX

## OTHER HEAT PUMP SCENARIOS – CLIMATE ZONE 5

Below we describe and show the costs of one alternative scenario for new homes, and two for retrofits. The results of our analysis of costs are shown in **Table 11** below.

### New Home – 2-Speed Heat Pump with 95% Efficient Backup Furnace

This scenario is not our ideal scenario for new homes, but some developers may feel more comfortable going with a less expensive heat pump system and a backup furnace. For this scenario, compared to our recommended scenario – installing a cold-climate heat pump with no backup furnace – the installed costs will be lower, and the annual heating costs will also be slightly lower. See **Table 11** below. Therefore, this is a practical solution, and could be a pathway for developers and builders to start to feel more comfortable with heat pumps in new homes.

Compared to the all-electric new home, the GHG emissions benefits for this option will be slightly lower, with the heat pump system reducing emissions by about 40% rather than 49%. Also, as we noted above, if the cold-climate heat pump system is incorporated into an all-electric new home, then the annual heating costs would be further reduced due to avoiding the fixed gas charges on the monthly bills. In addition, avoiding the new gas piping infrastructure to serve the new home will reduce the developer’s costs by \$4,000-5,000.

**Table 11: Comparison of Alternate Scenarios**

Scenario	Annual Heating Cost <sup>50</sup>			Incremental Installed Cost (compared to 95% eff. gas furnace and 16+ SEER AC)	
	95% Eff. Gas Furnace	Cold-climate HP	2-speed HP	Cold-climate HP	2-speed HP
New home	\$687	\$769	\$752	\$3,200	\$1,600
Existing home 1: cold-climate HP	\$847	\$898		\$4,000, plus ductwork	
Existing home 2: 2-speed HP, all-electric	\$847		\$1,130		\$2,000, plus ductwork

<sup>50</sup> Annual heating costs shown are using Denver/Xcel Energy rates.

## Retrofit of Existing Home (1) – Full Gas Furnace Replacement with a Ducted Cold-Climate Heat Pump

This scenario may appeal to the more environmentally-conscious homeowner, who wishes to completely eliminate the gas furnace, or as a means to help avoid investment in expansion of natural gas infrastructure.

For this all-electric retrofit scenario, the GHG emissions benefits will be greater, achieving about 49% emission reductions rather than 40%, compared with the 80% retrofit scenario – displacing 80% of gas consumption and keeping/installing a backup furnace. The annual heating costs will be about the same, as shown in **Table 11**.<sup>51</sup> However, the incremental initial costs will be significantly higher for the all-electric retrofit compared to the hybrid retrofit, because of the higher cost of the cold-climate heat pump systems compared to a 2-stage heat pump, plus the costs of duct system improvements. Or, if duct improvements are not practical, there would be additional costs for installing a mini-split heat pump system to serve the second floor.

In many homes the size and configuration of the existing duct system, which is sized and designed for high temperature furnace heating, will limit the ability of the cold climate heat pump to provide adequate heat output during the coldest temperatures and will require supplemental heating from the built-in electric strip heat. If the homeowner would like to limit the use of the inefficient electric strip heat, there are two options.

First, if the duct system can be accessed for improvements, adding new supply or return ducts, or zoning and trunk lines is a viable strategy to minimize the use of electric strip heating. However, the additional cost of duct system improvements will range from \$1,000-5,000.

If duct system modifications are not practical or possible, another option is to consider a dual heat pump system, with a smaller cold-climate heat pump to heat and cool the main floor and a mini-split heat pump system for the second floor. This option will eliminate the need for supplemental electric heating and duct improvements, however, there would be significantly increased costs to add a mini-split system to the second floor, probably at least \$10,000 (in addition to the cost of the heat pump for the first floor).

To sum up, compared to the 80% retrofit option, the all-electric option with cold-climate heat pumps would cost: a) \$3,000-7,000 more with duct improvements; or b) at least \$11,000 more if including the mini-split system for the second floor.<sup>52</sup>

## Retrofit of Existing Home (2) – Full Gas Replacement with a 2-Speed Heat Pump Instead of a Cold Climate Heat Pump

In this scenario, we reduce the initial costs for the ducted heat pump system by using a 2-speed heat pump rather than cold-climate heat pump. However, the annual heating costs would be 15-20% higher with the 2-stage heat pump, because the system would rely more on electric resistance heating for the colder months due to the heat pump's reduced heat output compared to

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<sup>51</sup> We assumed the mini-split heat pump serving the second floor will be slightly more efficient than the ducted heat pump serving the first floor.

<sup>52</sup> Both options include \$2,000 in additional costs for cold-climate vs. 2-stage heat pump, with option b) saving about \$1,000 for a smaller cold-climate heat pump for the first floor but adding ~\$10,000 for the mini-split system.

the cold-climate model. In addition, the constraints of the existing duct system described above also apply to this scenario. If duct improvements are required, this could add \$1,000-5,000 to the retrofit costs.

## OTHER HEAT PUMP SCENARIOS – OTHER CLIMATE ZONES

We provide scenarios of heat pumps in existing homes in climate zones 4, 6, and 7 in the “Heating and Cooling” section of Love Electric. See [loveelectric.org/heating-cooling/](http://loveelectric.org/heating-cooling/).

For new homes in Climate Zone 4, we suggest an efficient 2-stage or cold-climate heat pump, without a backup furnace. For this climate zone with a 2-stage heat pump, the annual heating costs will be slightly higher but close to those for the cold-climate heat pump, and the installed costs would be significantly lower.

## GHG EMISSIONS

As stated above, for electricity we used the projected marginal GHG emission factors for Colorado, for the period 2022-37, from NREL. NREL’s model includes all the recent state requirements and commitments for GHG emission reductions from Colorado’s utilities and generating companies.

The projected emission factors were generated using the “ReEDS” capacity expansion model, which projects the evolution of the electric sector over time. The long-run marginal emission rate is calculated by estimating what mixture of generation would serve a marginal increase in demand, taking into account the possibility of building new capital assets (such as wind and solar) in response to changes in end-use electrical load. The emission rates are calculated as hourly rates over the course of each year, taking into account daily and seasonal variations, and are then combined into the long-term rates for the period such as 15 years.<sup>53</sup>

## DETAILS ABOUT THE MODEL AND EQUIPMENT CHOICES

For energy consumption modeling of the heat pump and gas furnace systems, we used the Wright-Suite Universal 2021 HVAC modeling package, which uses ACCA Manual J, 8th Edition methodology for the load calculations. Wright-Suite Universal is one of the most widely-used load modeling software packages by the HVAC industry in the U.S. that is not tied to an equipment manufacturer.

Using this software, we developed models for new and existing homes, based on three Front Range locations within different utility service territories, with the electricity and gas rates listed

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<sup>53</sup> Pieter Gagnon, Senior Energy Systems Researcher, National Renewable Energy Laboratory (NREL), (personal communication), 9/30/21, [Pieter.Gagnon@nrel.gov](mailto:Pieter.Gagnon@nrel.gov). For more on the derivation of the 15-year projected marginal electricity factors, see “Cambium Documentation: Version 2020,” NREL, <https://www.nrel.gov/docs/fy21osti/78239.pdf>.

above. Based on HVAC equipment choices and weather data, the models provide outputs of electricity and gas consumption to meet the homes' annual heating needs.

## Weather Bin Data

- Denver and Erie – Denver Stapleton ASHRAE, 2017.
- Pueblo – Pueblo Memorial ASHRAE, 2017.

## Loads and Design Temperatures

New Home Models – representing a typical 2,000-2,500 ft<sup>2</sup> home built to the IECC 2018 energy code.

- Denver and Erie – Heat load: 36,104 Btu/hr @ -1 F (Cooling Load: 19,386 Btu/hr @ 100 F).
- Pueblo – Heating load: 35,474 Btu/hr @ 0 F (Cooling load: 20,009 Btu/hr @103 F).

Existing Home Models – representing a typical 2,000-2,500 ft<sup>2</sup> home in the Front Range built between 1985 and 2005.

- Denver and Erie – Heat load: 44,950 Btu/hr @ -1 F (Cooling Load: 22,473 Btu/hr @ 100 F).
- Pueblo – Heating load: 44,293 Btu/hr @ 0 F (Cooling load: 23,317 Btu/hr @103 F).

## HVAC System Modeling Configurations

We compared efficient heat pump systems with an Energy Star gas furnace and AC system. For our “efficient” heat pump system, we chose commonly available heat pump systems with the best combination of low annual heating costs and low installed costs, compared to the furnace and AC system.

### New Homes

1. Base system: standard 96% efficient natural gas furnace combined with a 2-ton 16 SEER single speed AC unit.
2. Heat Pump Hybrid System: a 4-ton two-speed 16 SEER/9.0 HSPF semi-cold climate heat pump combined with a standard 96% furnace.
3. Heat Pump Full Electric System: a 3-ton variable-speed 17 SEER/9.5 HSPF cold-climate heat pump with a 10 kW electric strip air handler.

### Existing Homes

1. Base system: standard 96% efficient natural gas furnace combined with a 2-ton 16 SEER single speed AC unit.
2. Heat Pump Hybrid System: a 4-ton two-speed 16 SEER/9.0 HSPF semi-cold climate heat pump combined with a standard 96% furnace.
3. Heat Pump Full Electric System: a 4-ton variable speed 17 SEER/9.5 HSPF cold climate heat pump with a 10 kW electric strip air handler.
4. Heat Pump Full Electric System: a 4-ton two-speed 16 SEER/9.0 HSPF semi-cold climate heat pump with a 10 kW electric strip air handler.

## Changeover Temperatures

For the heat pump hybrid system, 20 F was used as the outdoor changeover temperature. We found this to be an optimal balance point in order to maximize the heat pump's annual heating contribution, while also keeping the operating costs and initial costs down. Choosing this balance point also avoids oversizing the unit for the duct system in an existing home, or needing to oversize the ducts in a new home. For the all-electric configurations, the heat pump system was set to have the backup electric strip heating elements cycle on when necessary to supplement the heat pump, while minimizing the use of the electric strip heating to reduce the annual heating costs.