# Benefits of heat pumps for Southwest homes

## 2022 STUDY


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SWEEP
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 and clean transportation in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. For more information, visit: swenergy.org.

# EXECUTIVE SUMMARY

Across the Southwest states, interest in heat pumps has grown sharply in recent years, driven by new awareness of how this technology's cost-effectiveness, efficiency, improved performance, safety and reliability, and zero-carbon capabilities makes it a superior method for heating and cooling homes and businesses when compared to gas-powered systems and appliances. Heat pump and heat pump water heater (HPHW) models in production today can readily and affordably supplant central air-conditioners and gas furnaces in millions of Southwest homes.

Updating the analysis the Southwest Energy Efficiency Project (SWEEP) conducted in 2018, this report demonstrates that as heat pump technology has steadily improved over the past five years, so have the benefits and cost savings provided to homeowners, renters, homebuilders, and installers.

## TOPLINE FINDINGS FROM SWEEP'S ANALYSIS

- It costs about the same to build an all-electric home with a heat pump than to construct one with gas systems and appliances, regardless of whether it's in a warmer or cooler region of the Southwest.
- In warmer climate cities like Las Vegas and Phoenix, using a heat pump instead of gas will save residents of new and existing homes more than $100 annually, or 30%, on energy bills. Using heat pumps also results in reductions of one-half to two-thirds of the amount of carbon pollution a gas-powered home would produce.
- In cooler climate cities like Reno, Salt Lake City, and Albuquerque, installing heat pumps in new homes will result in heating bills roughly equivalent to gas-consuming ones, but the carbon emissions will be cut in half, which would greatly aid the efforts of cities, counties, and state governments to meet their climate targets. These savings will only grow as the energy grids in Nevada and other Southwest states transition to more renewable energy sources.

To help policymakers as well as utility companies accelerate adoption of heat pumps and heat pump hot water systems, the report contains the following recommendations:

- Utilities should offer rebates for cold-climate heat pumps (with no backup furnace for new construction), and additional measures that will incentivize building all-electric homes.
- SWEEP recommends that utility programs encourage homeowners to replace central AC systems with efficient heat pumps. To achieve this, utilities should eliminate or significantly reduce their rebates for central AC systems, while increasing the incentives

for heat pumps. To foster greater understanding and knowledge of heat pump and HPHW systems among installers, utilities should support and collaborate on contractor training programs.

- State public utilities commissions should create favorable rate structures that support heat pump usage, such as time-of-use (TOU) rate structures that provide lower daily off-peak rates. Heat pump water heaters can take advantage of this by avoiding the on-peak usage periods.
- To avoid expansion of gas piping infrastructure in new and existing developments, and the costs and impacts it incurs, state regulators must push electric utilities to provide higher rebates for all-electric new homes as well as retrofits of existing homes.
- Local governments must also expedite permitting and reduce fees for these projects, as well as revise their building codes to ensure new developments are required to be all-electric or are electric-preferred and electric-ready.

# CHANGING MARKET CONDITIONS

In 2018, SWEEP released "Benefits of Heat Pumps for Homes in the Southwest," which provided our analysis of the possible cost and greenhouse gas (GHG) emission reduction benefits of heat pumps, in both new homes and in retrofit applications, for five Southwest cities representing a variety of climates. Several things have changed in the last three years: gas prices have increased significantly in the past six months,[1] and heat pump technology has continued to improve. In addition, SWEEP and many other supporters of building electrification have a better understanding of the best applications of heat pumps as well as limitations.

While general support for building electrification has grown, some interests, 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.[2] Therefore, we decided to refresh our analysis and provide some updated recommendations.

The purpose of this report is to provide an updated analysis of the economic and GHG emissions benefits of air-source heat pumps and HPWHs in Arizona, New Mexico, Nevada, and Utah, for an average size, single-family home. (We wrote a similar report for Colorado in February 2022.[3])

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 seven Southwest cities.
- Projected 15-year GHG emission factors for the electricity grid in the four states mentioned (Arizona, New Mexico, Nevada, and Utah).
- Utility rebates for heat pumps and HPWHs in these cities and states.
- New proposed federal financial incentives for heat pumps and HPWHs.

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[1] 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 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 affecting gas production, and continued bankruptcies of smaller gas producers.

[2] See for example, "Assessment of Natural Gas and Electric Decarbonization in State of Colorado Residential Sector," Black Hills Energy and GTI, March 2021.

[3] "Benefits of Heat Pumps for Colorado Homes," SWEEP, February 2022, www.swenergy.org/pubs/heat-pump-study-2022.

We include both new home and retrofit scenarios. For both cost-effectiveness and climate benefits, we are comparing the heat pump systems versus gas space or water heating. It is already clear that compared to propane, fuel oil, or electric resistance space and water heating, heat pumps significantly reduce annual energy costs and GHG emissions (by 50% or more), so we did not update those comparisons.[4] In addition, according to the Energy Information Administration (EIA) data, about 64% of homes in the Southwest states mentioned above use gas for heating.[5]

We did not include multi-family housing in this study, as other work is being done to evaluate and provide suggestions for the multi-family sector. For example, a recent study of the economics of new low-rise, multi-family, all-electric housing in Utah found positive results, similar to those for single-family homes.[6]

## IMPROVEMENTS IN TECHNOLOGY

Within the last three years, there have been additional improvements in heat pump technology. More heat pump manufacturers are offering high-efficiency models, ranging from non-cold-climate heat pumps with single-stage or two-stage compressors, non-cold-climate heat pumps with variable-speed compressors, and cold-climate heat pumps with variable-speed compressors. (We define cold-climate heat pumps in the next section.)

[4] For recent comparisons of heat pumps and HPWHs vs. propane or electric resistance, see www.loveelectric.org/heating-cooling and www.loveelectric.org/hot-water.

[5] Energy Information Administration, Residential Energy Consumption Survey (RECS) - 2015, "Housing Characteristics," www.eia.gov/consumption/residential/data/2015.

[6] "The Economics of All-Electric New Construction in Utah," E3, February 2022, www.ethree.com/wp-content/uploads/2022/02/Economics-of-All-Electric-New-Construction-in-Utah-02.2022.pdf.

**Figure 1: Ducted Heat Pump**


Source: Loveelectric.org

There have been many successful installations of cold-climate heat pumps in recent years, demonstrating their ability to provide efficient heating in cold climates without a backup furnace. 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, which includes utilities, heat pump manufacturers, regional energy efficiency organizations, and other stakeholders, is helping to increase the successful installations of high-efficiency heat pumps. This 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 focus on air-source heat pumps. Ground-source heat pumps make sense in some applications such as commercial or perhaps multi-family buildings but are much more expensive.[7]

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.[8] In addition, three manufacturers are

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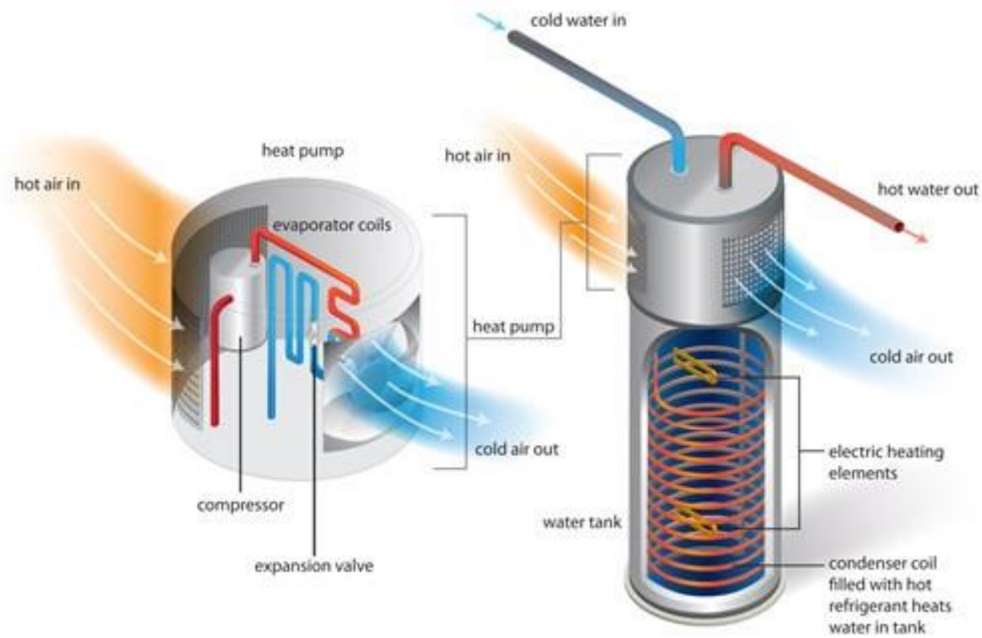
[7] Ground-source heat pumps are better able to maintain their heat output and efficiency at low outdoor temperatures and are better suited to serving hydronic heating systems.

[8] The Northwest Energy Efficiency Alliance (NEEA) maintains a list of "qualified" heat pump water heaters meeting its specifications, including grid-enabled, at this website: www.neea.org/img/documents/HPWH-qualified-products-list.pdf.

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.[9] 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.

**Figure 2: Heat Pump Water Heater**




Source: ENERGY STAR

## GROWING SUPPORT FOR ELECTRIFICATION

In the past three years, state and local government and utility support for building electrification has grown significantly. For residential and commercial buildings, the two largest fuel use applications that can be electrified are space heating and water heating. In this section we discuss the greening of the electricity grid, which provides the foundation for reducing GHG emissions through electrification, and utility rebates for heat pumps and HPWHs.

Beneficial electrification is an important element of the Southwest states' and the United States' efforts to significantly reduce GHG emissions in order to mitigate the effects of climate change. In addition to decreasing carbon emissions by converting fossil fuel uses to efficient electric

[9] "A New Generation of Heat-Pump Water Heaters is on the Way," Green Building Advisor, www.greenbuildingadvisor.com/article/a-new-generation-of-heat-pump-water-heaters-is-on-the-way.

technologies, other advantages of beneficial electrification include reducing customers' energy costs, improving the utilization of grid resources, and improving indoor air quality and safety.[10]

## Utility Clean Energy and GHG Reduction Goals

One important development in the last three years is the adoption of voluntary, and in some cases mandated, utility GHG emission reduction goals. **Table 1** below shows the utility or state clean energy goals for the four Southwest states in this study. These goals are partly in response to new state legislation affecting the regulated electric utilities, 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 climate targets provide the foundation for reducing GHG emissions through electrification of building fuel uses (mainly space heating and water heating). The declining carbon-intensity of the electricity grid is incorporated into our assumptions of electricity GHG emission rates, discussed below, and our findings regarding the climate benefits of heat pumps and HPWHs.

**Table 1: State GHG Emission Reduction Requirements**

| State | State Clean Energy Requirements or Utility Goals |
| --- | --- |
| Arizona | State utility commission approved Tucson Electric Power's plan to reduce GHG emissions by 80% by 2035. Separate voluntary agreements by Arizona Public Service and Salt River Project. |
| New Mexico | NM Energy Transition Act requires 50% renewable generation by 2030, 80% by 2040, for investor-owned utilities (Public Service of New Mexico, El Paso Electric, and Southwest Public Service). |
| Nevada | Senate Bill (SB) 358 (2019) requires investor-owned utilities (IOUs) to achieve 50% renewable generation by 2030; SB448 (2021) requires the IOUs to forecast how they could achieve 80% reduction in GHG emissions by 2030 from a 2005 baseline. |
| Utah | Rocky Mountain Power's voluntary goal is to reduce GHG emissions by 74% from 2005 levels by 2030. |

[10] This is the broader definition of beneficial electrification from the Beneficial Electrification League (BEL). See www.be-league.com. The definition from Colorado Senate Bill 246, passed in 2021, specifies only three benefits: a) reduced GHG emissions, b) more efficient utilization of grid resources, and c) reduced societal costs. "Societal costs" means the life-cycle costs of beneficial electrification measures for the consumer, plus the social costs of carbon dioxide and methane. See http://leg.colorado.gov/bills/sb21-246.

Although it varies somewhat between states, in general fuel use in commercial and residential buildings accounts for about 5-12% of total GHG emissions in these states.[11] And in general, residential buildings (including multi-family) account for about two-thirds of total GHG emissions from buildings. Within residential buildings, about 50-75% of the fuel use emissions are from space heating (depending on climate zone), and most of the rest comes from water heating, with a small amount from cooking, clothes dryers, and gas fireplaces.

## Utility Rebates

Most utilities in these four states provide rebates for heat pumps and HPWHs. **Table 2** provides a list of heat pump and HPWH rebates for the major electric utilities in Arizona, New Mexico, Nevada, and Utah. We provide our suggestions on what the ideal rebate levels and minimum efficiency requirements should be in the "Recommendations for Utility Programs" section.

[11] For Nevada, fuel use in commercial and residential buildings accounts for 11.5% of total GHG emissions, based on the most recent state GHG emissions inventory. For New Mexico, this percentage is only about 3.4% because of the state's high level of GHG emissions from oil and gas production, and because of the warmer climate. Utah and Arizona do not currently have state GHG emissions inventories, but Utah's percentage of emissions from commercial and residential buildings is probably similar to Nevada's, and Arizona's is probably similar to New Mexico's, because of its warmer climate.

**Table 2: Heat Pump and HPWH Rebates**

| Utility (City) | Heat Pump Rebate | HPWH Rebate |
|---|---|---|
| Arizona Public Service (Phoenix) | 0 | 0 |
| Tucson Electric Power (Tucson) | $650 with quality installation | $400 for ENERGY STAR with wireless, programmable timer/controller |
| Salt River Project (central AZ) | $150/ton for multi-stage, SEER 16+; $225/ton for variable-capacity, SEER 16+ | 0 |
| Public Service of New Mexico[12] (Albuquerque) | $465 for SEER 16+ | $825 for UEF 2.0+ |
| El Paso Electric (Las Cruces) | $100 per ton for SEER 16-17.9 | TBD* |
| NV Energy[13] (Las Vegas and Reno) | $500 for SEER 17+, HSPF 9.3+ | TBD* |
| Rocky Mountain Power (Salt Lake City)[14] | $1600 for 9.0 HSPF heat pump with new furnace | $550 for HPWH on qualified products list |

*These rebates are still being discussed and finalized.

## Heat Pump Installer Training

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

Only one of the utilities listed below, Rocky Mountain Power (RMP), has a training program for heat pump installers. In order to be listed as a registered trade ally, RMP in Utah requires its heat pump installers to earn a certification in HVAC from North American Technician Excellence (NATE). RMP also offers lunch and learn training sessions to its contractors and classroom-style events for heat pump distributors and HVAC contractors to familiarize them with the basics of heat pumps and with RMP's rebates. We urge other utilities to pursue similar programs to familiarize HVAC contractors with heat pumps and increase their proficiency in installing them.

[12] Public Service of New Mexico gives some of the heat pump or HPWH rebate to the wholesalers and installers, and some to the customer. The rebates shown are for "Tier 2 heat pumps" and HPWHs 55 gal. or less in size.

[13] NV Energy's heat pump rebates have several additional tiers not listed here.

[14] RMP offers many complicated categories and tiers of rebates for heat pumps. For homes heated with gas, the dual-fuel option is essentially the only option for a customer installing a new heat pump for the first time. See www.wattsmarthomes.com/heating-and-cooling/homeowners/dual-fuel-heat-pumps/UT.

# 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 different climate zones and electric and gas utility rates in each of the four states, we chose the following seven cities for our analysis:

- Phoenix, Arizona
- Tucson, Arizona
- Las Vegas, Nevada
- Reno, Nevada
- Albuquerque, New Mexico
- Las Cruces, New Mexico
- Salt Lake City, Utah

Phoenix and Tucson are in similar climates but are served by separate electric utilities. Las Vegas and Las Cruces are in warmer climate zones than Reno and Albuquerque, and Albuquerque is also served by a separate electric utility from Las Cruces.

### New Home Scenarios

**Climate Zone 5 (Salt Lake City, Reno, and Albuquerque)**

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 ($ft^2$), we provide the maximum heating demand at the design outside temperatures in the Appendix. 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[15]

[15] 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 www.neep.org/heating-electrification/ccashp-specification-product-list.

will perform efficiently without a backup furnace down to the "design" outside temperatures, such as 4 degrees F for Salt Lake City.

**Warmer Climates (Phoenix, Tucson, Las Vegas, and Las Cruces)**

For these cities, a cold-climate heat pump is not necessary, and we modeled an efficient two-stage heat pump with no backup furnace. See **Table 3** below for the heat pump efficiency specifications we modeled. We provide the maximum heating demands at the design outside temperatures in the Appendix.

## 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 heating needs.[16]

For all the cities, we assumed the existing homes have a maximum heating demand that is about 20% higher than for the average new home (mentioned above), because of less efficient initial construction.

**Climate Zone 5 (Salt Lake City, Reno, and Albuquerque)**

For the colder climate cities, 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.[17]

For retrofits in Climate Zone 5, we analyzed an efficient, 2-stage heat pump, sized to provide heating down to ~25 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). We expect this dual-fuel retrofit to be the most practical and common retrofit configuration for at least the next 5-7 years. It is also possible to install a cold-climate or 1- or 2-stage heat pump with no backup furnace. However, this may require installing new, larger ducts, which tends to be expensive. In addition, installing a cold-climate heat pump will further increase the installed costs of the heat pump retrofit.[18] Nevertheless, some customers may choose to spend more

[16] For more tips on these types of energy efficiency improvements, see "Insulation and Air Sealing," www.loveelectric.org/heating-cooling/.

[17] 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 would have 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.

[18] Another option is to choose a 1- or 2-stage heat pump rather than cold-climate; however, this option will increase the annual heating costs because the unit will rely more on electric resistance during the coldest temperatures.

money to avoid the backup furnace, and we evaluate and discuss these alternative all-electric retrofit scenarios in the Appendix.

For these three cities, choosing a "changeover temperature" of 25 degrees F will allow the heat pump to provide about 80-90% of the home's annual heating needs.

**Warmer Climates (Phoenix, Tucson, Las Vegas, and Las Cruces)**

For the warmer climate cities, we compare replacing the central AC system (and gas furnace when necessary) with an efficient one- or two-stage ducted heat pump system with no backup gas furnace. For these cities, as shown in **Table 18** (see p. 36), the capacity of the heat pump is the same as (or only slightly greater than for Las Cruces) the capacity of the AC system. This means the heat pump system can handle the home's full heating demand without exceeding the capacity of the existing ducts. Also, as mentioned above for new homes, a cold-climate heat pump is not necessary for these cities.

## Equipment Specifications and Installed Costs

Our equipment specifications are shown in **Table 3** 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 3** also shows our estimates of the installed costs for our recommended new home scenario (with the heat pump handling 100% of the heating load), and the retrofit scenarios for colder and warmer climate cities. As shown, the incremental costs for the heat pump are higher for the colder cities than for the warmer ones. For the colder cities, we need a larger capacity (in British thermal units per hour or Btu/hr) for the heat pump compared to the cooling capacity (also in Btu/hr) of the central AC system. We provide more details on this in the Appendix (see **Table 18**). In addition, for new homes in the colder cities, we need to install cold-climate heat pumps, which are significantly more expensive than 1- or 2-stage heat pumps.

### Table 3: Equipment Specifications and Installed Costs[19]

| Scenario | Heat Pump | Gas Furnace + Central AC[20] | |
|---|---|---|---|
| **Retrofit of Existing Home – Warmer Cities** | | | |
| System | Ducted, 1- or 2-stage, HSPF 9.0+, SEER 16+, electric strip backup | 96% AFUE | SEER 16+ |
| Installed Cost[21] | **$14,500** | **$13,500** | |
| **Retrofit of Existing Home – Colder Cities** | | | |
| System | Ducted, 1- or 2-stage, HSPF 9.0+, SEER 16+, 90% AFUE backup furnace[22] | 96% AFUE | SEER 16+ |
| Installed Cost | **$14,800** | **$13,000** | |
| **New Home – Warmer Cities** | | | |
| System | Ducted, 1- or 2-stage, HSPF 9.0+ (with electric strip backup)[23] | 96% AFUE | SEER 16+ |
| Installed cost | **$14,000** | **$13,000** | |
| **New Home – Colder Cities** | | | |
| | Ducted, cold-climate, HSPF 9.5+, with electric strip backup | 96% AFUE | SEER 16+ |
| Installed Cost | **$15,200** | **$12,000** | |
| **Water Heater - New or Existing Home** | | | |
| System | HPWH - UEF of 3.2 | Gas water heater - UEF of 0.68 | |
| Installed Cost | **$2,800** | **$1,900** | |

[19] HSPF means Heating Seasonal Performance Factor. AFUE means Annual Fuel Utilization Efficiency. SEER means Seasonal Energy Efficiency Rating.

[20] 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.

[21] 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.

[22] 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.

### 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.[24]

### 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 seven cities chosen. (The volumetric rates are the per kilowatt hour (kWh) or per therm components of the monthly rates.) We provide these in **Table 4** below. Gas rates have increased significantly since our 2018 report. The result of the higher gas prices is that more cities show a savings in heating costs with a heat pump. And for the remaining cities, the difference in annual heating costs between gas systems and heat pump systems is now very small (shown in the Findings section below).

[23] We would have modeled a 2-speed heat pump with these specifications, but the modeling software did not have any 2-speed heat pumps at the smaller capacity we wanted for the new home scenario. But the performance of the 1-speed and 2-speed HSPF 9.5 heat pumps are almost identical according to the model.

[24] See more details on HPWH performance and installation guidelines at www.loveelectric.org/hot-water/.

**Table 4: Electricity and Gas Rates**

| City | Electric Utility | Electricity Rate ($/kWh) | Gas Utility | Gas Rate ($/therm) | Ratio of Electricity to Gas Price |
|---|---|---|---|---|---|
| Phoenix, AZ | Arizona Public Service | $0.1120/ $0.1022[25] | Southwest Gas | $1.4060 | 2.3 |
| Tucson, AZ | Tucson Electric Power | $0.1120/ $0.1094[26] | Southwest Gas | $1.4060 | 2.3 |
| Las Vegas, NV | NV Energy | $0.0754/ $0.0804 | Southwest Gas | $0.8130 | 2.5 |
| Reno, NV | NV Energy | $0.0783/ $0.0806 | NV Energy | $0.5835 | 3.9 |
| Las Cruces, NM | El Paso Electric | $0.0887/ $0.0877 | City of Las Cruces | $0.8031 | 3.2 |
| Albuquerque, NM | Public Service of New Mexico | $0.1166/ $0.0840 | New Mexico Gas | $0.9264 | 3.7 |
| Salt Lake City, UT | Rocky Mountain Power | $0.0978/ $0.0799 | Dominion Gas | $0.9127, $0.8499[27] | 3.1 |

We show the ratio of electric to gas price in the last column above (using equivalent units, e.g., converting $/therm to $/kWh). This ratio is an important factor in determining the annual heating costs for heat pumps compared to those for gas heating. And as shown, this ratio varies quite a bit between the cities.

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.[28] The life-cycle costs include the initial installed costs of the equipment, and the net present value (NPV) of the 15-year fuel costs for heating. (We used a 12-year life for the water heater comparison.)

[25] These are the TOU rates that would apply to heat pumps and HPWHs. For heat pumps, we used all hours during the heating season. For HPWHs, we assumed programming and controlling to avoid up to four of the peak rate hours (e.g., 3-7pm weekdays).

[26] 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 50% of the heat pump's consumption is at the lower rate above, and 50% of consumption is at the higher (over 500 kWh/month) rate. For HPWHs, we assume the lower rate applies.

[27] The second rate shown is for hot water. Dominion is the only gas utility in any of these cities with a separate rate for hot water.

[28] 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.

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 of carbon dioxide equivalent ($CO_2e$), from the most recent federal update.[29] The purpose of including the social cost of carbon and methane is to account for additional benefits associated with the heat pump, 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. For example, 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 building electrification program cost effectiveness.[30]

# 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.[31] 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. We provide the state 15-year marginal emission factors below in **Table 5**. 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 state clean energy goals or GHG emission reduction commitments by the major electric utilities in the four states.

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.[32] 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

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[29] 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, www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

[30] "Electric Utility Promote Beneficial Electrification," Colo. Senate Bill 21-246, https://leg.colorado.gov/bills/sb21-246.

[31] 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 and programs to encourage more heat pumps?"

[32] 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 because 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.

rate from the gas distribution system through the home's equipment to be 0.8%.[33] We think this is a 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.[34]

**Table 5: State GHG Emission Factors for Electricity**

| State | 15-Year Projected Marginal Emission Rate (lb CO2/kWh) (for heat pump comparison) | 12-Year Projected Marginal Emission Rate (lb CO2/kWh) (for HPWH comparison) |
|---|---|---|
| Arizona | 0.642 | 0.688 |
| New Mexico | 0.585 | 0.632 |
| Nevada | 0.600 | 0.628 |
| Utah | 0.665 | 0.702 |

[33] 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.

[34] "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, www.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 for most of the warmer climate cities (all of them except Las Cruces), heat pumps have lower life-cycle costs than the gas heating alternatives. For two of the colder climate cities — Albuquerque and Salt Lake City — heat pumps have slightly lower annual heating costs than gas heating. However, due to the higher costs of heat pumps in the colder cities, the heat pumps' life-cycle costs are higher than those of the gas heating alternatives (without including utility, local government, or federal rebates). Our analysis also shows that the GHG emissions benefits of heat pumps and HPWHs versus gas space and water heating are significant.

## HEAT PUMPS

**Tables 6 and 7** below show our comparison of annual heating costs for new homes and for existing homes with heat pump retrofits.[35] For the warmer cities shown in Table 6, the annual heating costs with heat pumps are significantly less than for gas heating for the first three cities shown, and only slightly (about 7%) less for Las Cruces.

For the colder climate cities, the annual heating costs with heat pumps are slightly less than with gas heating for Albuquerque and Salt Lake City, but slightly higher with heat pumps for Reno. This difference is because of the higher ratio of electric to gas prices for Reno compared to the other cities.

[35] We did not analyze cooling costs, but it's also very likely that cooling costs will be significantly lower for the new homes in the colder cities with very efficient cold-climate heat pumps.

### Table 6: Annual Heating Costs – Warmer Cities

| City and Scenario | Gas Furnace | | | Heat Pump | | |
|---|---|---|---|---|---|---|
| | Gas Use (therms) | Electricity Use (kWh) | Annual Heating Costs ($) | Gas Use (therms) | Electricity Use (kWh) | Annual Heating Costs ($) |
| **New Home** | | | | | | |
| Phoenix, AZ | 198 | 188 | **$299** | 0 | 1589 | **$178** |
| Tucson, AZ | 299 | 285 | **$454** | 0 | 2509 | **$281** |
| Las Vegas, NV | 359 | 342 | **$343** | 0 | 3009 | **$227** |
| Las Cruces, NM | 481 | 458 | **$427** | 0 | 4221 | **$374** |
| **Retrofit of Existing Home** | | | | | | |
| Phoenix, AZ | 229 | 218 | **$346** | 0 | 1873 | **$210** |
| Tucson, AZ | 337 | 320 | **$512** | 0 | 2862 | **$321** |
| Las Vegas, NV | 412 | 392 | **$394** | 0 | 3479 | **$262** |
| Las Cruces, NM | 540 | 514 | **$479** | 0 | 4850 | **$430** |

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 25 degrees F changeover scenario, in which the heat pump provides about 80% of the annual heating needs.

**Table 7: Annual Heating Costs – Colder Cities**

| City and Scenario | Gas Furnace | | | Heat Pump and Gas Furnace | | |
|---|---|---|---|---|---|---|
| | Gas Use (therms) | Electricity Use (kWh) | Annual Heating Costs ($) | Gas Use (therms) | Electricity Use (kWh) | Annual Heating Costs ($) |
| **New Home** | | | | | | |
| Albuquerque, NM | 651 | 495 | **$661** | 0 | 5259 | **$613** |
| Reno, NV | 829 | 630 | **$533** | 0 | 6934 | **$543** |
| Salt Lake City, UT | 876 | 666 | **$865** | 0 | 7630 | **$746** |
| **Retrofit of Existing Home** | | | | | | |
| Albuquerque, NM | 729 | 555 | **$740** | 51 | 5792 | **$721** |
| Reno, NV | 930 | 707 | **$598** | 114 | 7042 | **$634** |
| Salt Lake City, UT | 983 | 747 | **$970** | 175 | 7070 | **$890** |

Note: for the new home scenario, we are assuming a cold-climate heat pump with no backup furnace.

**Tables 8 and 9** summarize the GHG emissions benefits of heat pumps vs. gas furnaces. For the retrofit scenario in the colder climate cities, the results shown are based on the 25 degree F changeover temperature discussed above. As shown, the total GHG emission reductions with heat pumps compared to gas furnaces are about 60% for new homes and for retrofits in the warmer cities and range from 45% to 58% for retrofits in the colder cities. These are average values over the 15-year period, from 2022-37, based on the projected significant reductions in carbon intensity of the electricity grid in these states over this time period. We explain this further in the Appendix. (Note that a home with a rooftop solar photovoltaic (PV) system will have even lower GHG emissions from heating with a heat pump.)

### Table 8: GHG Emissions Comparison – Warmer Cities

| City and Scenario | Gas Furnace | | Heat Pump and Gas Furnace | | |
|---|---|---|---|---|---|
| | GHG Emissions (lb CO2/yr) | GHG Emissions incl. Methane Leakage (lb CO2e/yr) | GHG Emissions (lb CO2/yr) | GHG Emissions including Methane Leakage (lb CO2e/yr) | Percentage Emission Reductions for Heat Pump incl. Methane |
| **New Home** | | | | | |
| Phoenix, AZ | 2,437 | 2,645 | 1,020 | 1,020 | **61.4%** |
| Tucson, AZ | 3,681 | 3,995 | 1,611 | 1,611 | **59.7%** |
| Las Vegas, NV | 4,405 | 4,782 | 1,805 | 1,805 | **62.3%** |
| Las Cruces, NM | 5,896 | 6,400 | 2,469 | 2,469 | **61.4%** |
| **Retrofit of Existing Home** | | | | | |
| Phoenix, AZ | 2,819 | 3,060 | 1,203 | 1,203 | **60.7%** |
| Tucson, AZ | 4,148 | 4,502 | 1,838 | 1,838 | **59.2%** |
| Las Vegas, NV | 5,056 | 5,488 | 2,087 | 2,087 | **62.0%** |
| Las Cruces, NM | 6,619 | 7,185 | 2,837 | 2,837 | **60.5%** |

### Table 9: GHG Emissions Comparison – Colder Cities

| City and Scenario | Gas Furnace | | Heat Pump and Gas Furnace | | |
|---|---|---|---|---|---|
| | GHG Emissions (lb CO2/yr) | GHG Emissions incl. Methane Leakage (lb CO2e/yr) | GHG Emissions (lb CO2/yr) | GHG Emissions including Methane Leakage (lb CO2e/yr) | Percentage Emission Reductions for Heat Pump incl. Methane |
| **New Home** | | | | | |
| Albuquerque, NM | 7,906 | 8,590 | 3,076 | 3,076 | **64.2%** |
| Reno, NV | 10,077 | 10,947 | 4,159 | 4,159 | **62.0%** |
| Salt Lake City, UT | 10,692 | 11,612 | 5,076 | 5,076 | **56.3%** |
| **Retrofit of Existing Home** | | | | | |
| Albuquerque, NM | 8,854 | 9,619 | 3,985 | 4,038 | **58.1%** |
| Reno, NV | 11,305 | 12,281 | 5,558 | 5,677 | **52.8%** |
| Salt Lake City, UT | 11,998 | 13,030 | 6,751 | 6,935 | **44.7%** |

**Table 10** and **11** provide summaries of the life-cycle heating costs and total incremental life-cycle costs for a heat pump compared to a gas furnace system. As shown in Table 10, for three of the warmer cities (all except Las Cruces), heat pumps have lower life-cycle costs than gas heating (highlighted in red). Table 11 shows that for the colder cities, the life-cycle costs with heat pumps are higher than those for gas heating. As mentioned above, installed costs for cold-climate heat pumps are higher than for 1- or 2-stage heat pumps. And as explained above, the incremental costs for retrofits with a 1- or 2-stage heat pump are also slightly higher for the colder climate cities compared to the warmer cities. In addition, the heat pumps' annual heating costs compared to gas is higher for the colder cities compared to the warmer ones, mainly due to higher ratios of electric to gas prices.

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 heating 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.)

In these tables, we also show the net present value of the GHG emission reductions using the social cost of carbon and methane, which is about $2,100 2,600 for new and existing homes in the colder cities, and $600-1,700 for the warmer cities. These values (e.g., $2,100 for Albuquerque) indicate the amount of utility or local government rebates that would be justified from a societal perspective. For Albuquerque, a rebate of $2,100 would more than offset the life-cycle incremental costs for the heat pump retrofit, but not for the heat pump in a new home. However, in an all-electric new home, the avoided cost of the gas piping will more than offset the rest of the incremental costs for the heat pump. (We discuss this further in the “All-electric New Homes” section below.)

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

**Table 10: Life-Cycle Costs for Heat Pumps – Warmer Cities**

| City and Scenario | Gas Furnace | Heat Pump | | | |
|---|---|---|---|---|---|
| | NPV of Heating Costs ($) | NPV of Heating Costs ($) | 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) |
| **New Home** | | | | | |
| Phoenix, AZ | $3,221 | $1,914 | $1,000 | ($306) | **$635** |
| Tucson, AZ | $4,883 | $3,022 | $1,000 | ($861) | **$931** |
| Las Vegas, NV | $3,694 | $2,441 | $1,000 | ($252) | **$1,163** |
| Las Cruces, NM | $4,591 | $4,026 | $1,000 | $435 | **$1,536** |
| **Retrofit of Existing Home** | | | | | |
| Phoenix, AZ | $3,726 | $2,256 | $1,000 | ($469) | **$726** |
| Tucson, AZ | $5,502 | $3,448 | $1,000 | ($1,055) | **$1,041** |
| Las Vegas, NV | $4,239 | $2,823 | $1,000 | ($416) | **$1,329** |
| Las Cruces, NM | $5,154 | $4,626 | $1,000 | **$472** | **$1,699** |

**Table 11: Life-Cycle Costs for Heat Pumps – Colder Cities**

| City and Scenario | Gas Furnace NPV of Heating Costs ($) | Heat Pump NPV of Heating Costs ($) | 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) |
|---|---|---|---|---|---|
| **New home** | | | | | |
| Albuquerque, NM | $7,107 | $6,595 | $3,200 | **$2,688** | **$2,154** |
| Reno, NV | $5,733 | $5,838 | $3,200 | **$3,305** | **$2,652** |
| Salt Lake City, UT | $9,300 | $8,023 | $3,200 | **$1,924** | **$2,553** |
| **Retrofit of existing home** | | | | | |
| Albuquerque, NM | $7,960 | $7,772 | $1,800 | **$1,591** | **$2,184** |
| Reno, NV | $6,431 | $6,645 | $1,800 | **$2,188** | **$2,531** |
| Salt Lake City, UT | $10,435 | $9,152 | $1,800 | **$942** | **$2,276** |

Notes: Assumes cold-climate heat pump (no furnace) for new homes, and 1- or 2-stage heat pump with backup furnace for existing homes. 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 12** summarizes the annual energy costs for HPWHs compared to gas water heaters and shows that HPWHs cost $9 per year less than gas water heaters for homes in Reno, and $144 less for homes in Phoenix. We also included standard electric water heaters (electric resistance) in this comparison. **Table 13** provides the GHG emissions for water heaters and shows that HPWHs reduce GHG emissions by 65%-70% compared to gas water heaters.

### Table 12: Annual Costs for Water Heaters

| City | HPWH Electricity Use (kWh/yr) | HPWH Annual Costs ($) | Std. Electric Water Heater Electricity Use (kWh/yr) | Std. Electric Annual Costs ($) | Gas Water Heater Gas Use (MMBtu/yr) | Gas WH Annual Costs ($) |
|---|---|---|---|---|---|---|
| Phoenix, AZ | 920 | **$94** | 3100 | $317 | 14.78 | **$208** |
| Tucson, AZ | 920 | **$101** | 3100 | $339 | 14.78 | **$208** |
| Las Vegas, NV | 920 | **$74** | 3100 | $249 | 14.78 | **$131** |
| Reno, NV | 950 | **$77** | 3100 | $250 | 14.78 | **$86** |
| Las Cruces, NM | 920 | **$81** | 3100 | $272 | 14.78 | **$119** |
| Albuquerque, NM | 950 | **$80** | 3100 | $260 | 14.78 | **$137** |
| Salt Lake City, UT | 950 | **$76** | 3100 | $248 | 14.78 | **$126** |

### Table 13: GHG Emissions of Water Heaters

| City | HPWH | | Gas WH | | |
|---|---|---|---|---|---|
| | Cons. (kWh/yr) | GHG Emissions (lb CO2/yr) | Cons. (MMBtu/yr) | GHG Emissions including Methane Leakage (lb CO2e/yr) | Percent Reduction for HPWH Compared to Gas WH |
| Phoenix, AZ | 920 | 634 | 14.8 | 1,884 | 66.4% |
| Tucson, AZ | 920 | 634 | 14.8 | 1,884 | 66.4% |
| Las Vegas, NV | 920 | 578 | 14.8 | 1,884 | 69.3% |
| Reno, NV | 950 | 596 | 14.8 | 1,884 | 68.3% |
| Las Cruces, NM | 920 | 582 | 14.8 | 1,884 | 69.1% |
| Albuquerque, NM | 950 | 667 | 14.8 | 1,884 | 64.6% |
| Salt Lake City, UT | 950 | 601 | 14.8 | 1,884 | 68.1% |

**Table 14** shows the life-cycle costs of HPWHs. The life-cycle costs of a HPWH in Reno are about $800 greater than for a gas water heater, but are about $140 less than for a gas water heater in Phoenix. Again, this difference is because of the varying ratios of electricity to gas prices. If rebates were provided equal to the social cost of carbon and methane, the HPWH would have lower life cycle costs for all cities except Reno, Las Cruces, and Salt Lake City.

**Table 14: Life-cycle Costs for Water Heaters**

| City and Scenario | Gas Water Heater: NPV of Heating Costs ($) | HPWH: NPV of Heating Costs ($) | 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) |
|---|---|---|---|---|---|
| **New homes or replacements of water heaters in existing home[36]** | | | | | |
| Phoenix, AZ | $1,908 | $864 | $900 | **($144)** | **$417** |
| Tucson, AZ | $1,908 | $924 | $900 | **($84)** | **$417** |
| Las Vegas, NV | $1,201 | $680 | $900 | $379 | **$436** |
| Reno, NV | $792 | $703 | $900 | $811 | **$430** |
| Las Cruces, NM | $1,090 | $742 | $900 | $552 | **$434** |
| Albuquerque, NM | $1,257 | $733 | $900 | $376 | **$406** |
| Salt Lake City, UT | $1,154 | $697 | $900 | $444 | **$428** |

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 gas piping to the new home, which amounts to $4,000-5,000 per home, as shown in **Table 15**. For the homeowner, not having any gas service avoids all the monthly fixed costs from the gas utility, which add up to about $150 per year (varies by gas utility). These cost benefits are also summarized in Table 15. 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.[37]

In addition, electric cooking provides substantial health and safety benefits. Several studies have found that nitrogen oxide emissions from cooking with gas leads to increased asthma in

[36] 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).

[37] We also recognize that for some new home developers in the colder climate cities, installing 1- or 2- stage heat pumps with a backup gas furnace (rather a cold-climate heat pump with no backup furnace) may be a helpful first step before they feel comfortable with all-electric developments.

children.[38] A recent study also found that there is significant methane leakage from gas stoves, even when they are not being used.[39] Electric cooking and heating also reduces risks from potential carbon monoxide poisoning.

On top of these benefits, many people are discovering that induction cooking offers better performance than cooking with gas.[40] 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, since induction cooking requires pots and pans with magnetic properties (iron or steel).

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

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[38] "Gas Stoves: Health and Air Quality Impacts and Solutions," RMI, Physicians for Social Responsibility, 2020, www.rmi.org/insight/gas-stoves-pollution-health.

[39] Eric D. Lebel, Colin J. Finnegan, Zutao Ouyang and Robert B. Jackson, Methane and NOx 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.

[40] For example, see the short videos provided here: www.loveelectric.org/cooking/.

### Table 15: All-Electric New Home Cost Comparison - Reno[41]

| HVAC | 95% Efficient Gas Furnace and AC | Cold-Climate HP with Electric Strip |
|---|---|---|
| Initial Cost Excluding Ducts | $12,000 | $15,200 |
| Rebates | $0 | $500 |
| Total Cost After Rebates | $12,000 | $14,700 |
| Annual Heating Costs | $533 | $543 |
| **Water Heater** | **ENERGY STAR Gas Water Heater (50 gal)** | **ENERGY STAR HPWH (50 gal)** |
| Installed Cost | $1,900 | $2,800 |
| Rebate | $0 | $0 |
| Total Cost after Rebates | $1,900 | $2,800 |
| Annual Heating Costs | $86 | $77 |
| **Infrastructure Costs** | **Gas** | **Electric** |
| Electrical modification to go all-electric | $0 | $1,000 |
| External gas piping for the development (per home) | $2,500 | $0 |
| Gas meter and utility hookup charge, and internal gas piping for 3.5 gas appliances | $2,600 | $0 |
| **Cooktop/Range Costs** | **Gas** | **Induction** |
| Initial cost | $1,800 | $2,900 |
| **Total Equipment/Infrastructure Costs** | **$20,800** | **$21,400** |
| Fixed gas charges (on monthly bills) | $168 | $0 |
| Total annual heating costs (not including cooking) | $787 | $619 |
| **NPV of Heating Costs - 15 years** | **$8,404** | **$6,661** |
| **Total NPV of Costs** | **$29,204** | **$28,061** |

[41] We used gas and electricity rates from NV Energy for Reno in this comparison, as well as NV Energy's rebates.

# 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, focusing on seven cities in four Southwest states. Compared to SWEEP's 2018 residential heat pump study, heat pumps and HPWHs are now more cost-effective, due to increasing heat pump efficiency and the recent significant increase in gas prices, which we expect to continue.

In addition, 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 or most of the home's heating needs is a relatively easy first step towards greater heat pump adoption. This will lower the home's annual heating costs in most locations, while also reducing the home's carbon emissions.

Though the gap is narrowing, heat pumps still cost more to install than a central AC system, so heat pump rebates are very helpful. Fortunately, most of the major electric utilities in the four states covered in this report are now offering rebates for heat pumps and HPWHs.

In addition, 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. We encourage utilities to consider developing training programs and requirements to increase contractors' familiarity and proficiency with heat pump installation.

By focusing on the most cost-effective applications and continuing to improve contractor training and other outreach efforts, the number of successful heat pump installations will increase. 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 all-electric heat pump systems in warmer climates, or dual-fuel heat pump systems in colder climates.
- In new homes, heat pumps with no backup furnace in all-electric new homes (using a cold-climate heat pump in colder climates).
- 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 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 Congress and signed into law by President Biden. The combined utility and federal rebates (if these portions of the bill pass) will allow homeowners in any Southwest state to save money over the life of the heat pump or HPWH, while also significantly reducing their carbon footprint.

## GENERAL RECOMMENDATIONS

- For new homes in colder climates (Climate Zone 5), we recommend that developers and builders install cold-climate heat pumps without a backup furnace (but with appropriately sized supplemental auxiliary electric heat).
- For new homes and retrofits of homes in warmer climates we recommend an efficient 1- or 2-stage heat pump with a heating efficiency (HSPF) of 9.0, with appropriately sized supplemental auxiliary electric heat.
- For retrofits of homes in colder climates with central AC and a gas furnace, we recommend replacing the AC system with an efficient 1- or 2-stage heat pump, and keeping (or replacing as needed) the furnace to heat the home for outside temperatures below ~25 degrees F. This will allow the heat pump to provide about 80% or more of the home's annual heating needs.
- For retrofits in colder climates, 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 16**. 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 recommend 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 eliminate or significantly reduce their rebates for central AC systems while offering larger incentives for heat pumps.
- Utilities should support and collaborate on heat pump and HPWH contractor training programs.

**Table 16: Model Utility Heat Pump and HPWH Rebates**

| Heat Pump | Rebate Amount | Minimum Specifications | Suggested Applications |
|---|---|---|---|
| **Air Source Heat Pump** | | | |
| 1-2 ton heat pump | $700 ($400 in warmer climates) | HSPF 10+ | Mini-split systems for additions, partial fuel displacement |
| Non-cold-climate heat pump, 3 tons or greater | $1,800 ($1,000 in warmer climates) | HSPF 9.0+, SEER 16+, 1- or 2-stage compressor | Dual-fuel retrofits (or all-electric in warmer climates), temperatures down to 25 degrees F |
| Higher efficiency non-cold-climate heat pump, 3 tons or greater | $2,100 ($1,300 in warmer climates) | HSPF 9.5+, SEER 16.5+; variable speed compressor | Dual-fuel retrofits (or all-electric in warmer climates), temperatures down to 20 degrees F |
| Cold-climate heat pump, 3 tons or greater | $2,500 | a) HSPF 9.5+/10.0+ (ducted/ductless), b) SEER 16+, c) 3+ compressor stages or continuously variable, d) COP 1.75+ at 5 degrees F, and/or listed on NEEP's qualified cold-climate product list[42] | New construction or all-electric retrofits in climate zones 5 or higher, temperatures down to 0 degrees F or lower |

[42] 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: www.neep.org/heating-electrification/ccashp-specification-product-list.

| HPWH [43] | | | |
|---|---|---|---|
| Non-grid connected | $700 | UEF 3.2+ | |
| Grid-connected | $900 | UEF 3.2+ | |

## RECOMMENDATIONS FOR STATE PUBLIC UTILITIES COMMISSIONS

- Consider requiring regulated electric utilities to offer a TOU rate if they do not already do so. (The two utilities in the seven cities without TOU rates are RMP and Tucson Electric Power.) TOU rates 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 for dual fuel systems (in addition to those provided by the electric utilities), and for weatherization and other efficiency improvements to homes getting new heat pumps.
- To help avoid gas piping infrastructure to serve new developments, push electric utilities to offer higher rebates for all-electric new homes.
- To help avoid expanded gas piping infrastructure to serve existing areas, urge electric and gas utilities to offer significantly higher rebates for all-electric heat pump retrofits of homes in these areas (using cold-climate heat pumps if in colder climates).

## 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

[43] NEEA has a list of "qualified" heat pump water heaters here, almost all of which achieve the minimum UEF shown above: www.neea.org/img/documents/HPWH-qualified-products-list.pdf.

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, for the colder climate cities (Albuquerque, Reno, and Salt Lake City).

### 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 17** below, using costs for Reno. 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 50% rather than 60%. 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 17: Comparison of Alternate Scenarios**

| Annual Heating Cost[44] | | | Incremental Installed Cost (compared to 96% efficient gas furnace and 16+ SEER AC) | |
|---|---|---|---|---|
| 96% Efficient Gas Furnace | Cold-climate Heat Pump | 9.0 HSPF Heat Pump | Cold-climate Heat Pump | 9.0 HSPF Heat Pump |
| **New Home** | | | | |
| $533 | $543 | $582 | $3,200 | $1,600 |
| **Existing Home, All-electric Heat Pump Scenarios** | | | | |
| $598 | $624 | $730 | $4,000, plus ductwork | $2,000, plus ductwork |

Note: the values for the alternative scenarios are in bold.

## 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 gas infrastructure.

For this all-electric retrofit scenario, the GHG emissions benefits will be greater, achieving about 60% emission reductions rather than 50%, compared with the 80% retrofit scenario — displacing 80% of gas consumption and keeping or installing a new backup furnace. The annual heating costs will be about the same, as shown in Table 17.[45] However, the incremental initial costs will be significantly higher for the all-electric retrofit compared to the dual-fuel 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.

[44] Annual heating costs shown are using Reno/NV Energy rates.

[45] 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.

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.[46]

### 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 1- or 2-speed heat pump rather than a cold-climate heat pump. (We chose a 4-ton, two-speed 16 SEER/9.0 HSPF heat pump with a 10-kW electric strip air handler.) This reduces the initial costs by about $2,000 compared to the cold-climate heat pump.

However, the annual heating costs would be 20-25% 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 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

We provide additional scenarios for installing heat pumps in existing homes with other types of heating systems and in other climate zones (4-7), in the "Heating and Cooling" section of Love Electric. See loveelectric.org/heating-cooling/.

## GHG EMISSIONS

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

[46] 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 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, considering 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, considering daily and seasonal variations, and are then combined into the long-term rates for the period (15 years in this case).[47]

# DETAILS ABOUT THE MODEL

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 locations in the seven cities discussed in this study, with the electricity and gas rates listed 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

Weather bin data for all seven cities were pulled from ASHRAE 2017 data for the nearest airport to each city, with the exception of Las Vegas, for which ASHRAE 2013 data was used.

## Loads and Design Temperatures

For the modeling of new homes — representing a typical 2,000-2,500 $ft^2$ home built to the IECC 2018 energy code — the heating and cooling loads and design heating temperatures are shown in **Table 18**. For the modeling of existing homes, we assumed a typical 2,000-2,500 $ft^2$ home built between 1985 and 2005. The heating and cooling loads for the existing homes are also shown in Table 18.

[47] Pieter Gagnon, Senior Energy Systems Researcher, NREL, (personal communication), 9/30/21, Pieter.Gagnon@nrel.gov. For more on the derivation of the 15-year projected marginal electricity factors, see "Cambium Documentation: Version 2020," NREL, www.nrel.gov/docs/fy21osti/78239.pdf.

**Table 18: Loads and Design Temperatures**

| City and Scenario | Cooling Load (Btu/hr), Design Temperature | Heating Load (Btu/hr), Design Temperature | Difference in Heating load vs. Cooling Load (Btu/hr) |
|---|---|---|---|
| Phoenix – New Home | 28,400, @ 115 F | 20,600, @ 34 F | - |
| Phoenix – Existing Home | 30,500, @ 115 F | 23,500, @ 34 F | - |
| Tucson – New Home | 25,700, @ 110 F | 25,200, @ 26 F | - |
| Tucson – Existing Home | 27,500, @ 110 F | 28,500, @ 26 F | 1,000 |
| Las Vegas – New Home | 27,100, @ 112 F | 24,100, @ 26 F | - |
| Las Vegas – Existing Home | 29,000, @ 112 F | 25,000, @ 26 F | - |
| Reno – New Home | 21,000, @ 101 F | 36,000, @ 6 F | 15,000 |
| Reno – Existing Home | 22,500, @ 101 F | 40,500, @ 6 F | 18,000 |
| Las Cruces – New Home | 22,100, @ 104 F | 26,700, @ 23 F | 4,600 |
| Las Cruces – Existing Home | 24,000, @ 104 F | 30,000, @ 23 F | 6,000 |
| Albuquerque – New Home | 21,000, @ 100 F | 33,000, @ 11 F | 12,000 |
| Albuquerque – Existing Home | 23,000, @ 100 F | 37,000, @ 11 F | 14,000 |
| Salt Lake City – New Home | 22,500, @ 102 F | 37,500, @ 4 F | 15,000 |
| Salt Lake City – Existing Home | 24,000, @ 102 F | 42,000, @ 4 F | 18,000 |

As shown in the last column of the table, for the colder climate cities (Albuquerque, Reno, and Salt Lake City), the heat pump's capacity needs to be at least 12,000 Btu/hr (one ton) greater than the capacity of the central AC system. This contributes to the higher incremental costs for heat pumps vs. AC for these cities.

## Changeover Temperatures

For the heat pump hybrid system, 25 degrees 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 the need to oversize the ducts in a new home with a backup furnace). 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.