North American
Gas Heat Pump Collaborative
TECHNOLOGY FOR A CLEANER FUTURE

Accelerating North America's Decarbonization Strategy with Gas Heat Pumps

The North American Gas Heat Pump Collaborative

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Executive Summary

North American policymakers are setting aggressive decarbonization targets that aim to quickly reduce greenhouse gas (GHG) emissions quickly and equitably while maintaining power reliability. Currently, solutions are focused on renewable energy-powered electrification of homes, businesses, and transportation. Reducing carbon emissions from the gas industry must also be a priority because natural gas powers end uses and generates electricity for millions of homes and businesses.[1] Gas usage is on the rise and expected to grow over the next few decades, primarily to balance out negative impacts to grid systems and energy affordability arising from increased investments in electrification.[2]

Achieving equitable decarbonization that preserves grid reliability will require diverse solutions built to accommodate local and regional factors such as climate type, existing infrastructure, and consumer preferences. The gas industry must be a part of this with a focus on transitioning toward more sustainable end uses and cleaner sources of generation, like renewable natural gas and hydrogen.

Gas heat pumps are a ground-breaking technology that can support this vision: see Figure 1 on the next page for details about the technology. Gas heat pumps provide unprecedented energy gains and GHG reductions, and can significantly reduce consumers' energy bills. They perform well in cold climates, and they can be easily deployed at scale because they are compatible with existing building infrastructure and do not require costly upgrades to install.

Commercial gas heat pumps are market-ready and already achieving promising results across North America. The Collaborative expects residential gas heat pumps to become commercially available as early as 2023. This report outlines how this revolutionary product is a critical piece of the decarbonization puzzle.

How Gas Heat Pumps Support Decarbonization

Sustainable

Gas heat pumps are extremely energy-efficient, offering fuel efficiency above 100%.

Affordable

Gas heat pumps are a win for consumers, significantly lowering energy bills.

Feasible

Gas heat pumps offer plug-and-play installation at relatively low cost.

Reliable

Gas heat pumps perform well in all climates, so consumers experience the same level of comfort.

1 The US currently uses natural gas to generate over 40% of its electricity, while Canada uses natural gas to generate close to 9.5% of its electricity. According to projections from EIA's *Annual Energy Outlook 2021*, natural gas generation is forecasted to climb through 2050 due to the shutdown of coal generators and increased adoption of electrification. The Electric Power Research Institute (EPRI) also forecasted natural gas usage to grow considerably by 2050 in the 2018 *U. S. National Electrification Assessment (USNEA)*.

2 EPRI developed four potential electrification scenarios representing gradients of electrification progress in the U.S. by 2050, from a conservative scenario to a transformative scenario. Across all four forecasts, EPRI predicted an increase in electricity load, a reduction of CO_2 emissions, and an increase in natural gas consumption.

What is a Gas Heat Pump?

Gas heat pumps are a highly energy-efficient technology used for space heating and cooling, and water heating in commercial and residential sectors. Non-residential products are currently available, but residential gas heat pumps have not been commercialized yet in North America. The Collaborative expects residential products to hit the market as early as 2023. These products operate similarly to other heat pump technologies where heat is moved from one place ("the source") to another place ("the sink"). A common example of heat pump technology is a refrigerator which moves heat from inside the refrigerator ("the source") to outside the refrigerator ("the sink") by using refrigerants and heat exchangers. Like electric heat pumps, gas heat pumps efficiently move heat from the outside of a facility to its interior, and like electric heat pumps, some gas heat pumps can reverse this process for a cooling effect (see Figure 1).

Gas heat pumps differ from their electric counterparts in the fuel they use and in how they pressurize refrigerant. Manufacturers are developing three types of gas heat pump technologies: engine-driven vapor compression, sorption (absorption/adsorption), and thermal compression. Each type uses different refrigerants and pressurization methods.[3]

Figure 1 shows how gas heat pumps extract heat from surrounding air and transfer it to heat or cool buildings in a simple three-step process: 1) Outside air is pulled into the system. Fans pull warmth out of the air from the "source" into the heat pump, 2) Heat from natural gas combustion is added to ambient heat. Heat from the air and a gas burner is transferred to the refrigerant, 3) Heated air is pumped into the home.

Figure 1. How a Gas Heat Pump Works

3 For more information on how each of these technologies function, please see ***The Gas Heat Pump Technology and Market Roadmap*** by the Gas Technology Institute and Brio.

How Gas Heat Pumps Support Decarbonization

Gas heat pumps' ability to efficiently use fuel, drive down consumer costs, perform well in all climates, and integrate into existing systems makes them a critical part of climate change mitigation. This section describes how gas heat pumps contribute to decarbonization policy objectives.

Gas Heat Pumps Have Superior Sustainability

Unparalleled Efficiency

This cutting-edge technology is the first gas technology to offer fuel efficiencies greater than 100%. Gas heat pumps can produce as much as 1.6 units of energy for every unit of energy they consume by capturing readily available heat from the ambient air.[4] Gas heat pumps' superior performance in comparison to baseline, conventional gas equipment results in a significant decrease in the fuel needed to heat buildings and water, and yields substantial reductions in greenhouse gases (GHGs).[5,6]

Case Study: Some Gas Heat Pumps Further Drive Sustainability by Using Refrigerants with Low or No Global Warming Potential

Project Drawdown identified refrigerants as the most impactful factor on climate change in the construction industry and forecasted a 50.5 Gigaton reduction in CO_2-equivalent (CO_2e) emissions by transitioning to refrigerants with a low GWP. GWP is a metric for measuring and comparing how much heat various GHGs trap in the atmosphere in comparison to carbon dioxide equivalent (CO_2e), with lower numbers being better for the environment. For example, ammonia has a GWP of zero (i.e., ammonia does not contribute to global warming), and CO_2 has a GWP of one. Refrigerants commonly used in electric air-source and gas engine-driven heat pumps--R134a and R410a--have GWPs of 1,430 and 2,100, respectively.

Some gas heat pump technologies are integrating refrigerants with low or even no GWP:

- Gas absorption heat pumps (GAHPs) use refrigerants like ammonia, water, lithium bromide, and CO_2 which have very low or zero GWP.
- Thermal compression heat pumps use helium and CO_2 which have very low or zero GWP.

Additional GHG Reductions from Source Emissions

GHG emissions come from both the site and source of a power system. **Site** emissions are produced onsite at a home or business when a consumer uses an appliance such as a furnace or water heater. **Source** emissions include site emissions plus emissions resulting from converting raw fuel to electricity or heat, and emissions from the transmission and delivery of energy to a site. When factoring in source emissions, studies show that gas heat pumps produce fewer emissions than other decarbonization strategies such as electric heat pumps and high efficiency gas furnaces (**see Case Study above**).

Compatible with Fuels of the Future

Gas heat pumps are designed to be compatible with lower carbon fuels of the future, like renewable natural gas (RNG) and hydrogen blends, paving the way for the gas industry to transition to cleaner fuel sources in the coming years.

Sustainable Refrigerants

Refrigerants are one of the biggest contributors to climate change. Unlike electric heat pumps, gas systems use refrigerants with low or no global warming potential (GWP), thereby rendering gas heat pumps even more climate-friendly than alternative technologies.[7]

4 ***The Gas Heat Pump Technology and Market Roadmap***. Gas Technology Institute and Brio. October 2019.
5 Reed, Scott. ***Thermally Driven Heat Pumps: The Fastest Possible Way to Decarbonize Our Building Heat Loads***. Stone Mountain Technologies, Inc. July 2019.
6 In the 2020 report, ***Optimizing Energy Efficiency in Residential Heating Applications - What are the Options? What are the Impacts?***, Franklin Energy evaluated site and source emissions of four technologies in residential homes in northern Illinois– an electric heat pump, a natural gas heat pump, a condensing gas furnace, and a baseline gas furnace. Evaluators also examined annual carbon dioxide equivalent (CO2e) emissions and annual operating costs. Although electric heat pumps had the lowest site emissions in this study, they used the most source energy (energy used at the generation level) and produced the most emissions per year. Gas heat pumps consumed the second least amount of site energy and performed best across all other metrics.
7 CO_2e emissions are a way to standardize the impacts of emissions; in this study they include the 100-year Global Warming Potential (GWP) of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2).

Gas Heat Pumps are Feasible

When considering the pace at which we need to decarbonize, policymakers must consider the feasibility of various solutions. How quickly can we deploy technology? And how much will it cost us? Decarbonizing space and water heating is an expensive endeavor given the high initial cost of emerging technologies. Due to their compatibility with existing building infrastructure, gas heat pumps are a relatively cost-effective option that can be quickly brought to scale.

Easy to Install

Unlike other high-efficiency alternatives, gas heat pumps do not require upgrades to a home or building's existing infrastructure, such as new electrical panels for electric heat pumps or larger gas lines for tankless gas water heaters. Instead, manufacturers design gas heat pumps to use the infrastructure that is already available in a building, like existing ductwork and piping.

Versatile as Stand-alone or Add-on Solutions for Efficiency Improvements

In addition to their ability to function as stand-alone pieces of equipment, gas heat pumps can be added onto existing heating systems to significantly improve incumbent systems' efficiency. The Atmospheric Fund's 2018 report **Gas Absorption Heat Pumps: Technology Assessment and Field Test Findings** evaluated the performance of two gas absorption heat pumps during winter and spring months in Toronto, Canada. Two units were installed as a coupled system to support a large existing boiler system that provided space and domestic water heating to a large, multi-unit residential facility. Before the addition of the gas heat pumps, the existing boiler system had an average efficiency of about 54%. By supplementing this system with gas heat pumps, the average efficiency of the entire system improved to 114%.[8] The Atmospheric Fund analyzed system performance, finding that even at -5.9°C (21.4°F), the system performed at above 100% efficiency (1.04 COP) and reduced emissions compared to the baseline gas equipment.

8 The system had a mean Coefficient of Performance (COP) of 1.14.

Gas Heat Pumps are Affordable and Support Equity Goals

Policymakers recognize the need to keep consumer energy bills low, particularly for low- to moderate-income consumers and those with high energy burdens, while pursuing decarbonization. According to data from the 2020 U.S. Census, nearly 28% of the U.S. population falls into a low-income bracket.[9] In addition, the American Council for an Energy Efficient Economy reports that rural households shoulder a higher energy burden than households in other areas of the U.S.: on average, rural households spend 4.4% of their income on energy bills, compared to a national average of 3.3%. Low-income rural residents face even higher energy burdens, with several areas reporting energy burdens of 15% or greater.

Low Operational Costs

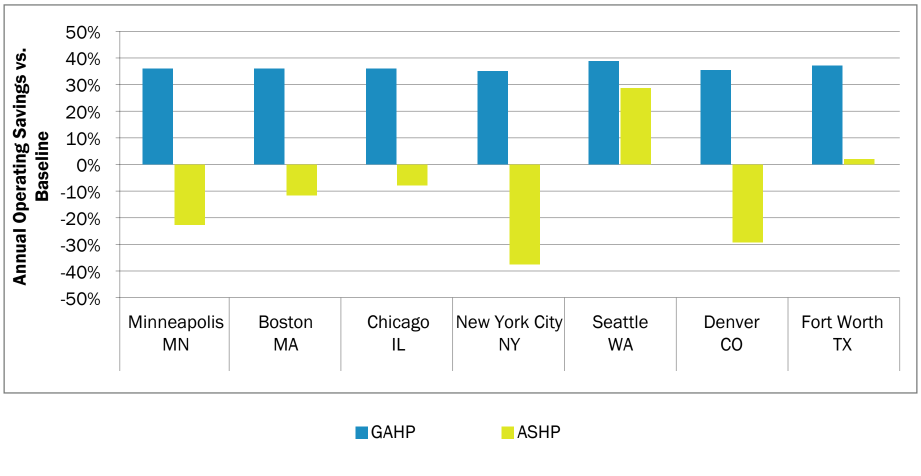
Several studies compare the operational cost of gas heat pumps to baseline equipment and other high-efficiency gas and electric alternatives. Results vary depending on several local factors including weather, climate, and energy costs, but most often gas heat pumps are a winner for consumers. For example, in 2016, the gas heat pump manufacturer Stone Mountain Technologies, Inc. (SMTI) and the hydronics manufacturer A.O. Smith partnered with the Gas Technology Institute (GTI) to examine how replacing a mid-efficiency gas furnace with prototype gas absorption heat pumps (GAHPs) and an electric air-source heat pump (ASHP) would affect a large home's energy use and operating costs in seven U.S. cities. The study found that GAHPs resulted in lower operating costs than both the ASHPs and the baseline equipment in all seven cities (see Figure 2). The operating cost of the ASHP was lower than that of baseline equipment in two of the cities, but was higher in the other five cities.[10]

Case Study: Commercial Gas Heat Pumps Can Reduce Operational Costs

Beyond their superior cold climate capabilities, gas heat pumps efficiently heat and cool in other climate zones across North America. In 2019, GTI completed a 12-month case study using a gas heat pump to deliver simultaneous heating and cooling to a small commercial building in Lawrenceville, Georgia. GTI presented the results of this case study in the report *Warm-Climate Demonstration of a Three-Pipe Natural Gas Engine-Driven Heat Pump*, comparing the performance of a high-efficiency, all-electric system to the performance of the gas heat pump-powered system. The installation of a gas heat pump resulted in:

- Estimated cost savings of over $16,000 during the equipment's 15-year life compared to a high-efficiency, all-electric system (using these energy cost for the analysis -natural gas: $0.770/therm; electric energy: $0.0981/kWh, and electric demand: $8.24/kW)
- Lower annual energy costs compared to the high-efficiency all-electric HVAC systems and the conventional multi-zone rooftop unit (RTU)
- A reduction in peak electric demand of 8 kW when in heating mode and of 10 kW when in cooling mode when compared to an electric HVAC system
- A reduction in peak electric demand of 11 kW when in cooling mode when compared to an electric multi-zone RTU

Figure 2. Gas Heat Pumps Reduce Annual Operating Costs Compared to Baseline Equipment and Air Source Heat Pumps



9 Defined as individuals or families that have income below 200% of the federal poverty level (FPL).
10 ***Low-Cost Gas Heat Pump for Building Space Heating***. Stone Mountain Technologies, Inc., Gas Technology Institute, and A.O. Smith. 2016.

Relatively Low Installation Costs

Gas heat pump installation costs are relatively low since gas heat pumps are designed to function with existing building infrastructure. In contrast, upgrading a home's electrical panel to support electrifying the building's HVAC system can add thousands of dollars to the cost of the new electric HVAC equipment.[11]

Gas Heat Pumps are Reliable

Gas heat pumps are reliable from both consumer and utility perspectives.

Reliability to Consumers

The cold weather performance of gas heat pump technologies is one of their most exciting features. Since gas heat pumps generate heat from natural gas and do not rely on extracting heat from the ambient air, they are able to maintain relatively high efficiencies and operate closer to their rated capacity even in very cold temperatures (see Table 1). Electric heat pumps, in contrast, operate at reduced capacity and diminished efficiency at low temperatures and typically require backup heating systems.

Increased Grid Reliability

Utilities are already using natural gas to balance the new, higher electrical peaks occurring from the increased electrification of water and space heating equipment. Extreme cold- and hot weather events can trigger unexpected spikes when electric demand outpaces electric generation capabilities. Spikes in electric demand can lead to grid instability, power outages, and increased electricity production costs that can be passed down to consumers. Gas heat pumps offer a solution to help flatten the demand for electricity in areas where the pace of electrification is causing new, high-cost peak loads.

Case Study: Residential Gas Heat Pump Prototype Maintains Efficiency and Capacity at Freezing Temperatures

In its 2016 ***Low-Cost Gas Heat Pump for Building Space Heating*** study, SMTI and its partners--GTI and A.O. Smith—designed and tested two low-cost GAHP prototypes for residential space heating. The prototypes performed at greater than 100% efficiency at temperatures near and far below freezing (32oF) (see Table 1). Further, GAHP capacity did not drop off significantly until temperatures were well below freezing.[12]

Table 1. GAHP Performance at Different Temperatures

This table presents the performance of GAHPs across low temperatures (ranging from 47°F to -13°F or 8.3°C to -25°C) and shows that even in negative temperatures the GAHP maintains its capacity and exceeds 100% fuel efficiency.

Ambient Temperature (°F)	GAHP Fuel Efficiency (%)[13]	Capacity (Btu/hour)
47	1.50	79,584
35	1.44	79,703
17	1.37	71,919
-13	1.17	55,746

The Path Ahead

Gas and dual-fuel utilities are eager to reduce carbon emissions in the natural gas sector. Gas heat pumps are a promising solution that align with policy goals of equitable, reliable decarbonization, and they can be deployed quickly once products are commercially available (as early as 2023). The North American Gas Heat Pump Collaborative is a non-profit 501c3 organization funded by utilities, energy efficiency program administrators, efficiency organizations, and research organizations dedicated to advancing this solution through educational efforts and market transformation activities. For more information on gas heat pump technologies, market transformation, effective program designs, and efforts to drive decarbonization in the residential and commercial space heating, cooling, and water heating sectors, please contact the Collaborative (info@gasheatpumpcollab.org) or visit the website (gasheatpumpcollab.org) for extensive literature on gas heat pump performance.

11 HomeAdvisor estimates new residential electrical panels cost up to $4,000.
12 Regular electric heat pumps do not function efficiently below 25°F to 30°F (-2.8°C to -1.1°C). However, as a point of comparison, a field study of Mitsubishi's electric cold climate heat pump conducted in Minnesota found COPs ranging from 4.0 to 4.5 during the shoulder season, and between 1.0 and 1.5 during the coldest period. One split-ductless unit operated with a COP greater than 1.0 at -19°F.
13 The source document labels this column as COP (Coefficient of Performance) rather than GAHP Fuel Efficiency.