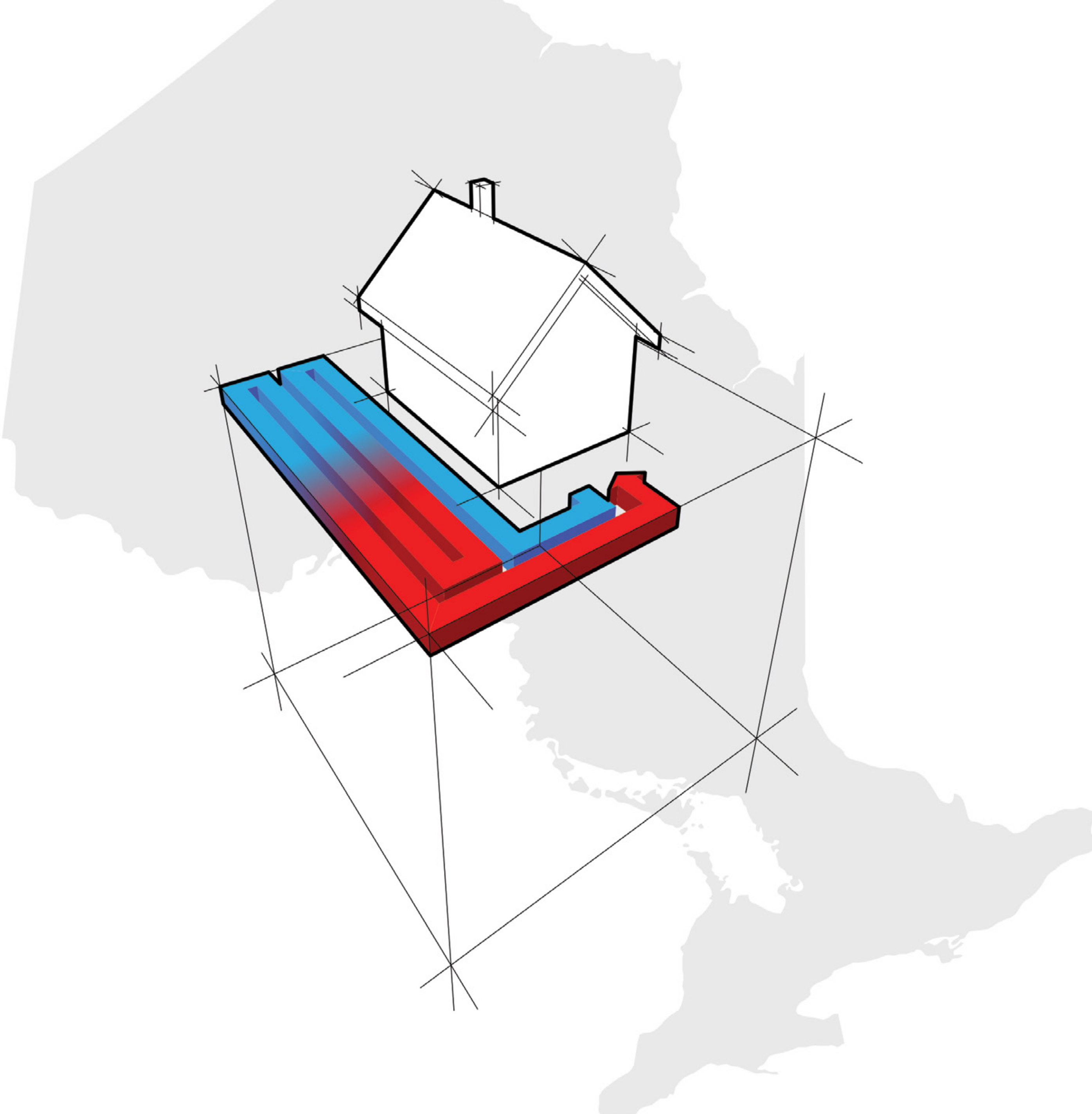
An Analysis of the Financial and Climate Benefits of Using

Ground-Source Heat Pumps

to Electrify Ontario's Gas-Heated Homes



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ONTARIO CLEAN AIR ALLIANCE RESEARCH

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Introduction

Ontario homeowners can save money, improve indoor air quality and help to combat climate change by choosing heat pumps to replace their end of life gas heating equipment. This report focusses on ground-source heat pumps that are extremely efficient and can save a homeowner more than $24,000 over their lifetime in Ontario. Switching heating systems to all-electric heat pumps is also a key strategy for most climate action plans[i,ii] because modern heat pumps can supply all of a home's space heating needs using a fraction of the energy used by conventional gas systems. As a result, the emissions savings are significant. Worldwide, the installation of heat pumps has been growing at a rate of 10% per year but Norway, a country with a climate similar to ours, leads the pack with a 60% adoption rate in residential homes[iii]. This is clearly the heating system of the future and homeowners would do well to plan now for their next system to be a heat pump.

This report models the lifetime savings and annual greenhouse gas reductions for Ontario single family homes that choose heat pumps over conventional gas-based equipment when their heating system is at the end of its life. The focus is on ground-source heat pumps (GSHPs) with a horizontal closed loop paired with an electric resistance water heater. Modeled outcomes for homes that choose other heat pump systems such as air source heat pumps (ASHPs) and ground source heat pumps with vertical loops are also provided (For my August 2022 analysis of ASHPs for Ontario's gas heated homes, see **Ontario Clean Air Alliance's website**). October 2022 electricity and methane gas rates are used in this analysis, and were assumed to remain constant over the lifetimes of the systems. Carbon pricing increased according to government schedules. The spreadsheet model used in this analysis is available for download on the **Ontario Clean Air Alliance website**. **Users can change the modeling assumptions and inputs such as the heating loads, heating system efficiencies, installation dates, inflation rates, and they can also model the impacts for select Ontario regions.**

Ground-source heat pumps can save a homeowner more than

$24,000

What are heat pumps?

Heat pumps are mechanical systems that move heat. Refrigerators and air conditioners are heat pumps that work in one direction to keep an area cool. Heat pumps for heating and cooling are reversible, that is they can replace a furnace by moving heat into a home in winter and replace a central air conditioner by moving heat out of a home in summer. Alternatively, they can move heat into water to provide hot water for showers, taps, laundry and even for space heating. Although heat pumps are a mature technology, they continue to improve, becoming more efficient, better suited to cold climates, quieter and more affordable[iv].

Ground-source heat pumps (GSHPs, a.k.a. geothermal or geo-exchange heat pumps) are electric heat pumps that exchange heat with the ground. GSHPs can be sized to meet 100% of a home's heating needs even on the coldest days and will maintain nearly 100% of its output and efficiency because the temperature underground varies far less over the course of the season, as compared to the air temperature[1]. These systems have underground loops that circulate an antifreeze solution between the ground and the heat pump's refrigerant. These loops can be installed horizontally below the frost line on sites with large open areas, or they can be installed on many sites using vertical boreholes[2]. Horizontal loops are currently more common in and best suited to rural homes with large properties but vertical loops may grow in popularity with new business models currently under development[v]. GSHPs also typically include a desuperheater that can pre-heat water and reduce the energy used by the home's water heater by an average of 50%. Electric resistance water heaters (EWHs) can provide the remaining heat required to make hot water. GSHPs can generate tens of thousands of dollars in lifetime savings relative to conventional equipment, despite their higher upfront costs. This is because GSHPs are among the most energy efficient heating and cooling systems available (GSHP can be 400% efficient or more[3]) and because the systems have long lifespans. Ground loops can last for more than 50 years and the associated heat pump equipment has an average lifespan of 20-25 years (we conservatively assume 20 years in this analysis)[vi], while modern conventional gas equipment last an average of 15 years.

All-electric air-source heat pumps (ASHPs) are a common alternative to GSHPs because they are cheaper and easier to install upfront. These systems

Heat pumps can replace a furnace by moving heat into a home in winter and replace a central air conditioner by moving heat out of a home in summer

[1] In practice, the sizing may vary by installation with some GSHPs sized slightly smaller to reduce upfront costs. In these cases, resistance heaters may supplement the heat on very cold days.

[2] Open loop systems that exchange heat with a groundwater source are also available, however, not all sites have access to groundwater and some sites are restricted from using the groundwater due to environmental concerns.

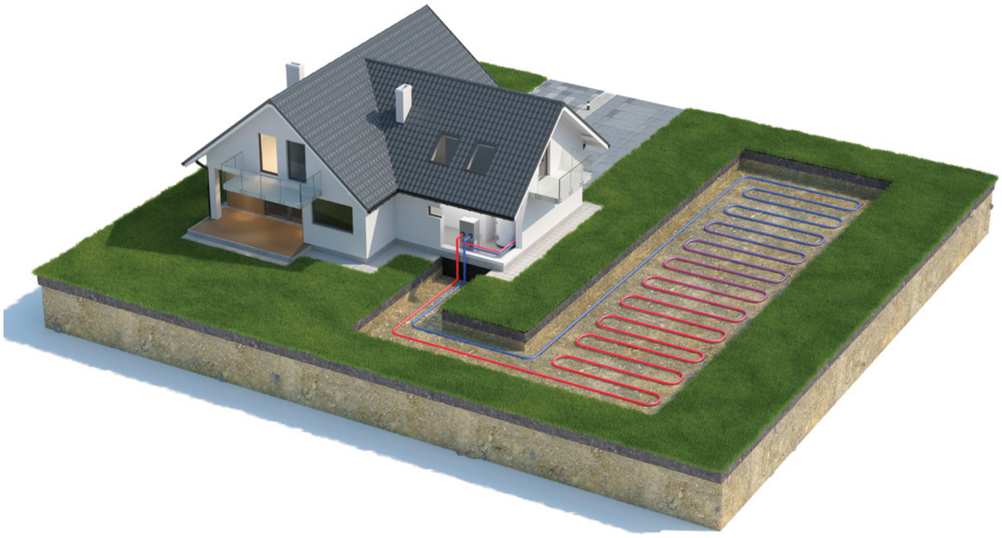
[3] Heat pump average seasonal efficiencies include all of the energy used by the heat pump over the heating season, including built-in electric resistance backup heaters for very cold days. This analysis uses a conservative 270% efficiency for air-source heat pumps and 370% efficiency for ground-source heat pumps.

exchange heat with the outside air. They can average 300% efficiencies over the winter months despite having to work harder to extract heat when outside temperatures are very low. Modern cold climate ASHPs with built-in backup resistance heaters can efficiently supply all of the heat needed by a home even in Ontario's climate[4], and have average lifespans of 15-20 years[vii]. Heat pump water heaters (HPWHs) can very efficiently provide hot water for these homes[5]. However, ground-source heat pumps provide greater bill savings over the long-run and provide significant climate and electricity-system benefits because they maintain their high efficiency levels on the coldest days when electricity systems can be strained, whereas air-source systems can drop from over 300% to closer to 100% efficiency.

In contrast, conventional gas systems are far less efficient and also contribute to poor indoor air quality. A furnace has a maximum theoretical efficiency of 100% because it cannot generate more heat energy than the energy contained in the fuel. With a conventional gas system, methane gas and combustion gases can leak into a home causing poor indoor air quality and putting residents at risk from carbon monoxide poisoning[viii,ix].

Although some homes may need to electrify stoves and other gas-burning appliances before disconnecting from the gas supply, these investments have the benefit of improving indoor air quality, eliminating the risk of carbon monoxide poisoning and saving the monthly gas fixed charges ($22-$23/month).

Ground-source heat pumps (GSHP, a.k.a. geothermal or geo-exchange heat pumps) are electric heat pumps that exchange heat with the ground



[4] Backup resistance heaters can be used to top up the heat provided by the heat pump when it struggles to extract enough heat from very cold outside air and is also used during defrost cycles. Cold climate ASHPs are often designed to provide full heating down to -20°C to -30°C, but this will vary by system and installation.

[5] The extra space heating required to compensate for the heat used by the HPWH as well as the reduced need for air conditioning in summer are included in our models.

GSHPs save money

Electric heat pumps such as those modeled here cost less to operate in Ontario than conventional gas systems for space and water heating because they are more efficient. Using October 2022 rates, an average rural Southern Ontario homeowner with gas systems would pay an average $2,014 per year for heating, cooling, hot water and gas connection, while a homeowner that switches to electric heat pumps for heating, cooling and hot water would pay an average $1,295 (ASHP/HPWH) or $1,082 (GSHP with horizontal loop/EWH) per year. Furthermore, the carbon prices applied to fossil fuels such as methane gas are increasing.

The lifetime costs of heat pump systems are also lower than conventional systems despite their higher upfront costs (upfront costs are outlined below). Over the 15 year lifespan of most systems, a home that fully electrifies[6] using an ASHP and HPWH will save an average rural Southern Ontario homeowner $9,785 relative to a comparable home that chooses to remain with conventional systems. Over those 15 years, a home with a horizontal loop GSHP and EWH in rural Southern Ontario will save an average homeowner $6,522 relative to conventional gas systems but at year 15, homeowners with the conventional gas systems would have to start replacing their furnace, air conditioner and water heater while the home with the GSHP can expect five to ten more years from their heating and cooling equipment, leaving only the EWH to be replaced. When examined over the longer 20-year lifespan of the GSHP equipment, the home that fully electrifies by installing a horizontal loop GSHP and EWH[7] using the Greener Homes Grant will save an average $24,193 relative to the home that remained with conventional gas systems (see Figure 1).

The costs modeled here are for an average Ontario home in the geographies listed. Costs may be higher or lower due to factors such as the age and energy efficiency of the home, the need for supportive upgrades including changes to ductwork and upgrades to the electrical service coming to the home. Many homes may also need to electrify other gas appliances such as stoves, fireplaces and dryers if they are to benefit from the gas connection fee savings (approximately $300 per year).

The home that installs a GSHP and EWH using the Greener Homes Grant will save an average

$24,193

relative to the home that remained with conventional gas systems over 20 years

[6] Although some homes may need to electrify stoves and other gas-burning appliances before disconnecting from the gas supply, these investments have the added benefit of improving indoor air quality, eliminating the risk of carbon monoxide poisoning and saving the monthly gas fixed charges ($22-$23/month).

[7] Assumes two installations of EWHs over the 20-years.

Figure 1 | **15-Year Cost for a Rural Southern Ontario Home**

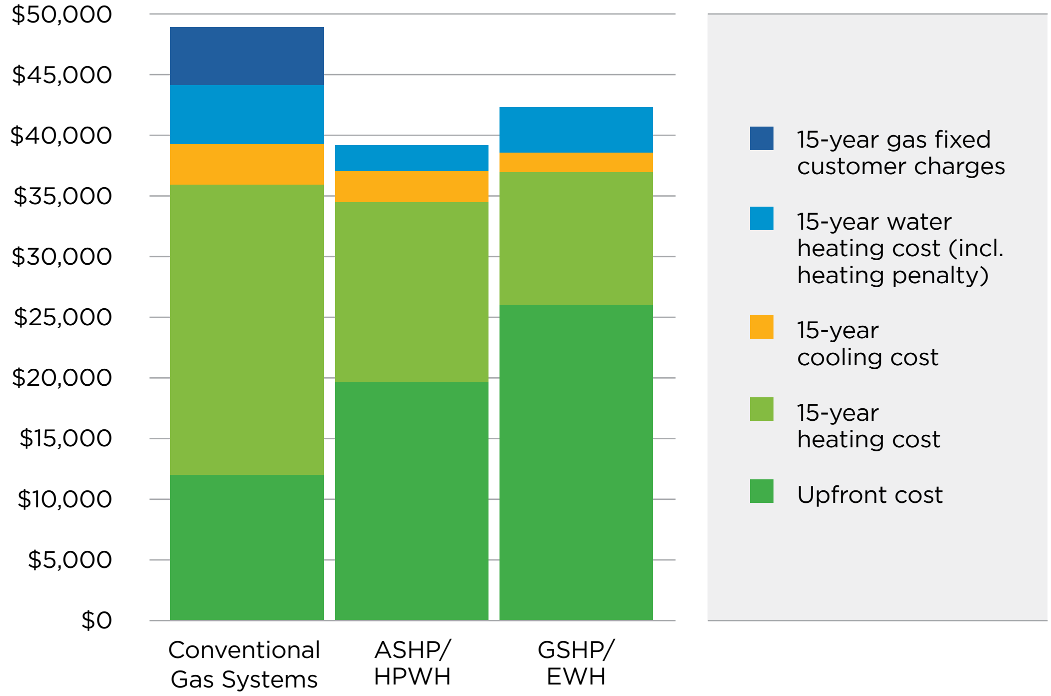
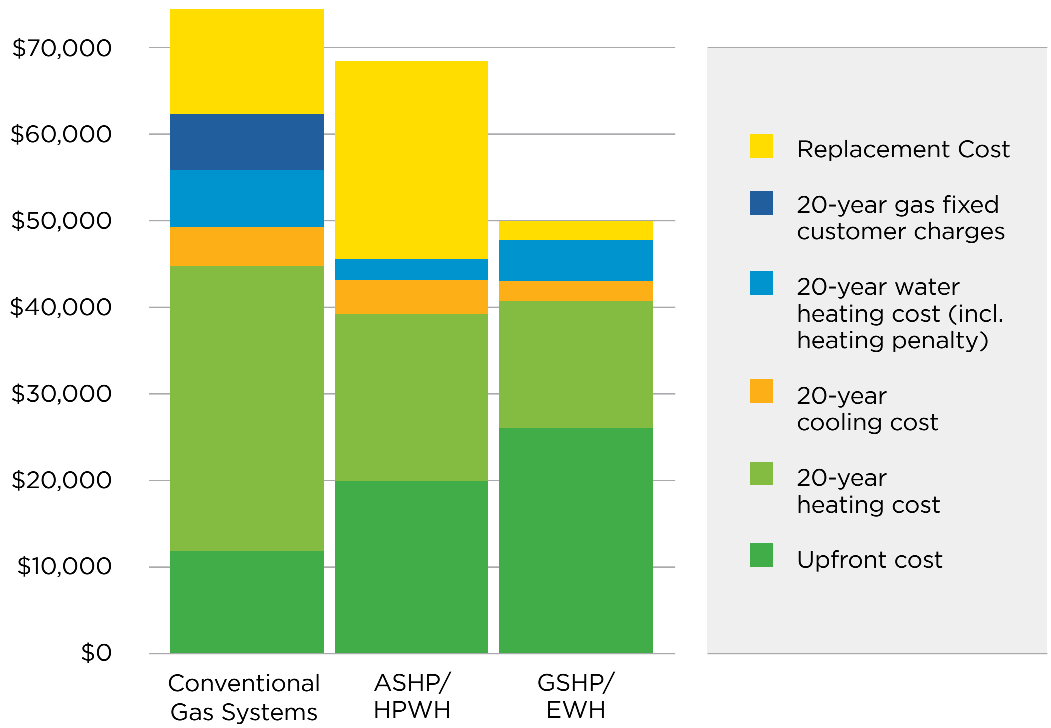


Figure 2 | **20-Year Cost for a Rural Southern Ontario Home**



The lifetime costs of heat pump systems are lower than conventional systems despite their higher upfront costs

Table 1 | Operational (2022) and lifetime costs for the conventional and heat pump systems used in this analysis

	Conventional systems	Air source heat pump systems	Ground source heat pump systems
Operational (2022)	$2,014	$1,295	$1,083
Lifetime (2036)*	$48,961	$39,176	$42,439
Lifetime (2041)	$74,245	$68,401	$50,052

*Lifetime costs include operational and upfront costs.

Heat pump systems can qualify for up to $5,000 in rebates and zero-interest loans from the federal Greener Homes Grant program. When these are applied, an ASHP/HPWH costs $19,750 upfront, a horizontal loop GSHP/EWH costs $26,200 upfront while a home that chooses conventional gas systems must pay $12,000 upfront for a gas furnace, central air conditioner and gas water heater. These costs are outlined in Table 2 below.

Table 2 | Upfront costs for the conventional and heat pump systems used in this analysis[8]

	Conventional systems		Heat pump systems		Ground source heat pump systems	
	Equipment	**Upfront installed cost**	**Equipment**	**Upfront installed cost**	**Equipment**	**Upfront installed cost**
Heating	Gas furnace (95% efficiency)	$5,000	ASHP (SCOP 2.7)	$19,000	GSHP (COP 3.7)	$27,000
Cooling	Air conditioner (SEER 13)	$5,000	ASHP (SEER 18)		GSHP (COP 5.8)	
Hot water	Gas water heater (67% efficiency)	$2,000	HPWH (EF 3.75)	$3,750	EWH (EF 0.91)	$2,200
Other costs	NA		- Electrical panel upgrade - Greener Homes grant	$2,000 -$5000	- Electrical panel upgrade - Greener Homes grant	$2,000 -$5000
Total (15 yrs)		$12,000		$19,750		$26,200
Total (20 yrs)		$24,000		$42,500		$28,400

Heat pump systems can qualify for up to **$5,000** in rebates and zero-interest loans

[8] Upfront costs were an average of several Southern Ontario installer quotes for a 3-ton system plus values obtained from a Dunsky analysis.

An average rural Southern Ontario home with a Greener Homes Grant for a horizontal loop GSHP and EWH will see an 11-year payback for that initial installation and a 15-year payback without the grant. For an ASHP with HPWH, the paybacks are 8-years with a grant and 12 without.

Even greater savings are possible when cost-effective energy efficiency upgrades to the building envelope are performed because total heating costs are reduced and smaller heating and cooling systems can be used.

GSHPs reduce emissions

Methane gas used to for space and water heating is the single largest source of carbon emissions for residential buildings and buildings overall accounted for nearly 19% of Ontario's total greenhouse gas emissions in 2013 (latest provincial inventory year)[x].

As Canada and the world moves to cut carbon emissions, electric heat pumps powered by low carbon electricity will become the dominant solution for space and water heating[xi,xii]. Here in Canada, the commitment is for net zero emissions by 2050[xiii] and electric heat pumps form the backbone of most municipal climate action plans. The City of Toronto's TransformTO Net Zero Existing Buildings Strategy, for example, aims to achieve net zero emissions from the residential sector by replacing "conventional heating systems with more efficient electric heat pumps while greening the provincial electricity grid"[xiv].

Over its lifetime, an average Ontario home with an electric ASHP and HPWH will generate 35% fewer carbon emissions from space and water heating than a comparable home that relies on gas. For a home with a horizontal loop GSHP and EWH, that values rises to 45%[9]. The homes with electric heat pumps are still responsible for carbon emissions because our electricity supply relies on methane gas for some of its generation. The federal government, however, has committed to achieving a net zero electricity supply by 2035[xv]. At that time, an average Ontario home will emit zero carbon emissions for space and water heating when electric heat pumps are used, but that same home on gas systems will emit 4.7 tonnes per year of carbon emissions from burning methane gas. If the emissions associated with drilling, extracting and transporting that methane gas to the home are included, the annual emission rise to 9.0 tonnes[xvi]: the equivalent to the annual emissions from of 2.8 fuel-burning cars[xvii].

Over its lifetime, an average Ontario home with a GSHP and electric water heater will produce 45% fewer carbon emissions than a gas heated home

[9] Marginal emission factors are used. If average emission factors were used instead, the emissions reductions would be greater.

Benefits under different scenarios

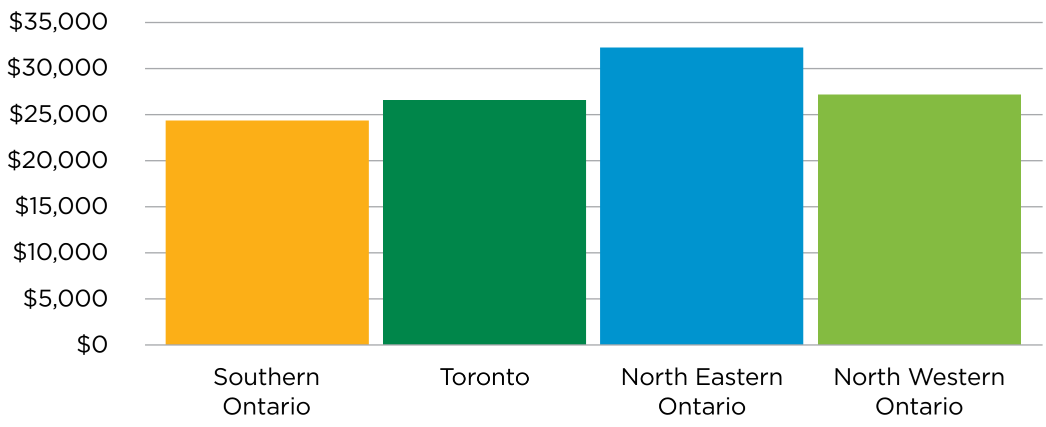
In all scenarios, the **electric heat pump systems save money** over conventional gas systems

The analysis above is based on an average home in rural Southern Ontario that installs either an ASHP paired with a HPWH or a GSHP with a horizontal closed loop paired with a EWH in 2022. We have extended this analysis to compare a home with a GSHP/EWH to conventional gas systems in different scenarios with respect to location, heating loads, ground loop installations, and carbon pricing (see Figures 2 and 3). Unless otherwise stated, lifetime savings are for the 20-year lifespan of a horizontal loop GSHP, assume the homeowner of the GSHP/EWH avoids paying monthly fixed gas customer charges that pay for gas distribution pipelines, and assume the homeowner uses the ($5,000) Greener Homes Grant to offset the upfront cost of the heat pump systems. In all scenarios, the electric heat pump systems save money over conventional gas systems, and GSHPs offer the best lifetime savings.

Location and building scenarios

Electricity and methane gas prices vary across the province. Figure 2 shows the lifetime (20-year) savings for a home that chooses a horizontal loop GSHP and EWH over gas systems in areas from the four major Enbridge Gas rate areas in Ontario[10]. Rural rates are the focus of this analysis as most GSHPs installs are in rural locations with the space for horizontal loops. The savings modeled here for Southern Ontario are clearly representative of savings expectations across the province.

Figure 3 | **20-Year savings for different parts of Ontario**



[10] All of these regions are found in climate zone V and will therefore have similar heat pump performances. The same heating and cooling loads were applied to homes across the province.

New Gas Communities

The Government of Ontario is supporting the expansion of Enbridge's system to bring methane gas to communities that do not currently have gas service (e.g., Selwyn). The nearly $27,000 cost per home[xviii] of expanding the gas system to serve new communities is being paid for by a $12 a year surcharge on gas rates of Enbridge's 3.6 million existing residential customers and by a $0.23 per cubic metre surcharge on the rates of the gas customers in the new gas communities. This means a homeowner will save an average $1,601 in operating costs in 2022 if a horizontal loop GSHP/EWH is installed in lieu of gas equipment and central air conditioning ($1,389 for an ASHP/HPWH). Over the 20-year lifespan of the GSHP, this translates into $37,588 of lifetime savings when upfront and operational costs are combined (see Figure 3), and $19,831 over 15 years for a home with an ASHP/HPWH.

Age of Homes

Older and leakier homes use more energy to heat and cool than the average home modeled here. While an average rural Southern Ontario home will save $24,193 over 20 years when choosing a horizontal loop GSHP/EWH system over conventional gas equipment, that value rises to $33,418[11] for a home built before 1946 that requires larger heating and cooling systems and more energy to heat and cool. The value drops to $20,132 for an average home built after 1984 that has better insulation and air sealing.

Installation Scenarios

The 3-ton GSHP system in this analysis uses a horizontal loop, which is the most common GSHP installed in Ontario, but it requires a large, open space for installation. Nearly any property with a suitable area that is typically 15 ft. by 15 ft. and accessible to drilling equipment can accommodate a GSHP with a vertical loop, however. The average upfront installation cost of a GSHP systems with a vertical loop is $27,000 in many locations after the Greener Homes Grant rebate but can be higher if drilling takes place on the Canadian Shield or in remote locations. The horizontal loop modeled here is $22,000 after the rebate and a lake loop, where the loops are sunk in a body of water can also cost $22,000 after rebate. New business models where a third party owns and rents access to a ground loop may become more common in the future and may significantly reduce upfront costs for homeowners. The operational costs of these systems will be roughly the same plus the rental fees.

Savings are greater in gas expansion communities where a $0.23 per cubic meter surcharge is applied to gas rates

[11] Assumes a 20% higher cost for a larger GSHP system including underground loops.

Carbon Pricing

The federal government has committed to increasing the price of carbon by $15 per year until it reaches $170 per tonne in 2030[xix]. After 2030, we used the conservative assumption that the price of carbon remains steady. If the price were to continue rising by $15 per year until 2035, as assumed by the IESO in its decarbonisation pathways study[xx], the 20-year savings for an average rural Southern Ontario home that chooses to switch from conventional gas to a horizontal loop GSHP and EWH system increases from $24,193 to $29,495.

The federal government has committed to increasing the price of carbon by $15 per year until it reaches $170 per tonne in 2030.

Figure 4 | Lifetime savings with a GSHP/EWH under different scenarios

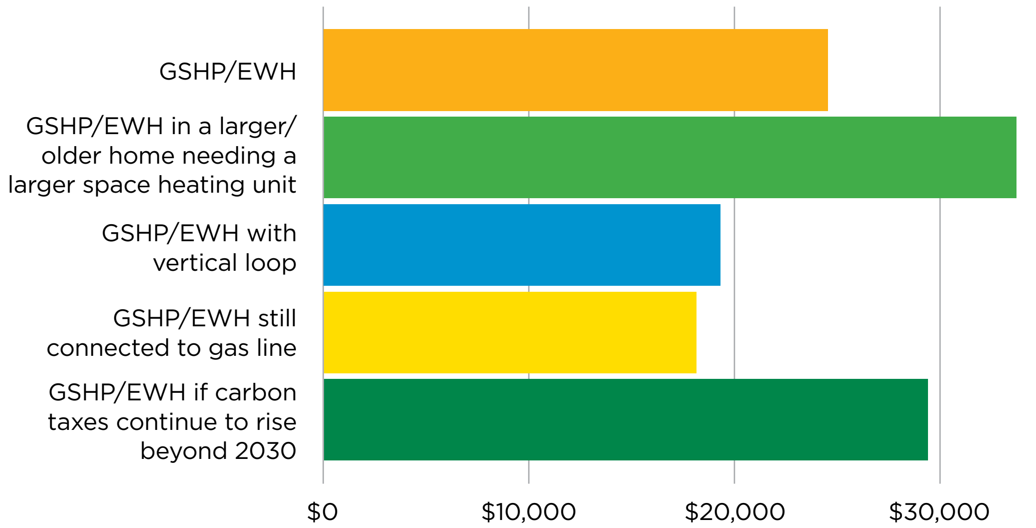


Figure 4 note: (1) Savings based on an average rural Southern Ontario home unless otherwise stated, (2) assumed installation date in 2022 [later installation dates result in increased savings each year as carbon prices increase], (3) all scenarios assume receipt of the $5,000 Greener Homes Grant, (4) unless otherwise noted, homes have disconnected from the gas supply, which may entail further investments in electrified appliances.

Under all of the modeled scenarios, the 20-year lifetime cost of electric heat pumps was less than that of conventional gas systems. Homes with ground-source heat pumps are the most-cost effective, saving the average homeowner $24,193 and sometimes more over 20 years relative to comparable homes with conventional gas systems.

Methane gas rates

Current gas and electricity prices (October 2022) were used in this analysis. However, electric heat pump systems are cost-effective even at much lower methane gas prices. On a 20-year lifetime cost basis with upfront costs included, fully electrifying the average rural Southern Ontario home with a horizontal loop GSHP/EWH will still be more cost-effective than traditional gas systems for space and water heating paired with an air conditioner even if gas commodity prices were to drop to zero. An ASHP/HPWH system will have lower lifetime costs than a conventional system even if gas commodity prices drop by 70%. This is mainly because fully electrifying will also save the high cost of delivering gas to the home through gas pipelines, save carbon costs, and save both heating and cooling costs through more efficient equipment.

Electricity system benefits

Our electricity system also benefits when homes choose GSHPs over all-electric ASHPs. Extra capacity and supporting infrastructure is needed to meet the increasing demand from electrified space and water heating. On cold winter days, ASHPs are less efficient, using more energy and more power to keep a home comfortable because the outside air contains less heat (although efficiency will not drop below 100%, which is the efficiency of resistance heaters). On very cold days ASHPs will therefore require significantly more power to heat homes than GSHPs and electricity systems must ensure they have the capacity to meet the demand on these extreme days. (This analysis does not consider hybrid ASHPs that use a gas furnace for heat on very cold days. These systems continue to burn fossil fuels and require continued dependence on methane gas infrastructure. They also require that customers continue to pay fixed charges to the gas distribution company (about $300/year), which can be avoided if customers fully electrify and disconnect from the gas system.)

Further considerations

Advanced planning is essential for homeowners wishing to install a ground-source heat pump to save money and reduce carbon emissions. A first step might be to invest in improved insulation and air sealing to benefit from immediate savings on heating and cooling costs while reducing the size of heat pump needed to heat and cool a home. Shifting other appliances (stoves, fireplaces, dryers, etc.) off methane gas ensures the home can disconnect from the gas pipeline system, improve indoor air quality[xxi] and save hundreds of dollars per year in fixed connection fees. Future-proofing the home by upgrading to a 200 amp electrical panel will not only support electric heat pumps, but also electric vehicle chargers. A GSHP requires underground loop systems with anti-freeze solutions that transfer heat between the heat pump refrigerant and the ground. Digging trenches for

Fully electrifying will also save the high cost of delivering gas to the home through gas pipelines, save carbon costs, and save both heating and cooling costs

horizontal loops or drilling vertical boreholes must be arranged well in advance of the replacement date for a heating and cooling system: when a furnace fails is not the time to consider a GSHP!

Each home and each site is different and homeowners should seek multiple quotes from qualified installers before investing in heat pumps. Ground source heat pump installers should have IGSHPA (International GSHP Association) certification available from the HRAI (Heating Refrigeration and Air conditioning Institute of Canada). While many in the HVAC industry offer electric heat pumps, there are also many who remain ignorant of the capabilities of modern units and their cost-effectiveness, so it is wise to shop around.

Some homeowners may be concerned about the global warming potential of leaked refrigerants used in air conditioning and heat pump systems. Yet the climate change impact of such leaks are less than the impacts of behind the meter methane leaks in homes that use methane gas[xxii]. This concern is also expected to decrease with time as better low global warming potential refrigerants are phased in due to the Kigali Agreement to the Montreal Protocol.

Finally, it is worth asking insurance providers if insurance premiums can be lowered when the electrified home is disconnected from the gas supply.

Conclusions

Electric heat pump systems are the most cost-effective and climate-aligned options available for space and water heating in Ontario residential homes. Compared to conventional gas system, a rural Southern Ontario homeowner that chooses an ASHP and HPWH over a conventional gas system will save $9,785 over its 15-year lifespan. If they instead choose a horizontal loop GSHP paired with an EWH, they will save $24,193 over its 20-year lifespan. As electric heat pumps gain market share, their technologies improve, and governments make stronger investments in climate policies, these savings could increase. The carbon emissions savings are impressive, with a 35% reduction in emissions for ASHP/HPWHs and 45% reduction for GSHP/EWHs now and a 100% reduction once our electrical grid is net zero emission. Electric heat pumps are the heating systems of the future, and GSHPs in particular are worth the additional planning and upfront investments.

Electric heat pump systems are the **most cost-effective and climate-aligned options** available for space and water heating in Ontario residential homes

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THE ONTARIO CLEAN AIR ALLIANCE, established in 1997, successfully led the campaign to phase-out dirty coal power in Ontario. We are now working to move our province towards a 100% renewable energy future.

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