Heating Electrification:
Policies to Drive Ground-Source Heat Pump Adoption

Prepared for:

Heating, Refrigeration and Air Conditioning Institute of Canada

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Submitted to:

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About Dunsky

Founded in 2004, Dunsky supports leading governments, utilities and others across North America in their efforts to **accelerate the clean energy transition, effectively and responsibly**.

Working across the buildings, renewable energy and clean mobility sectors, we support our clients through three key services: we **quantify** opportunities (technical, economic, market); **design** go-to-market strategies (programs, plans, policies); and **evaluate** performance (with a view to continuous improvement).

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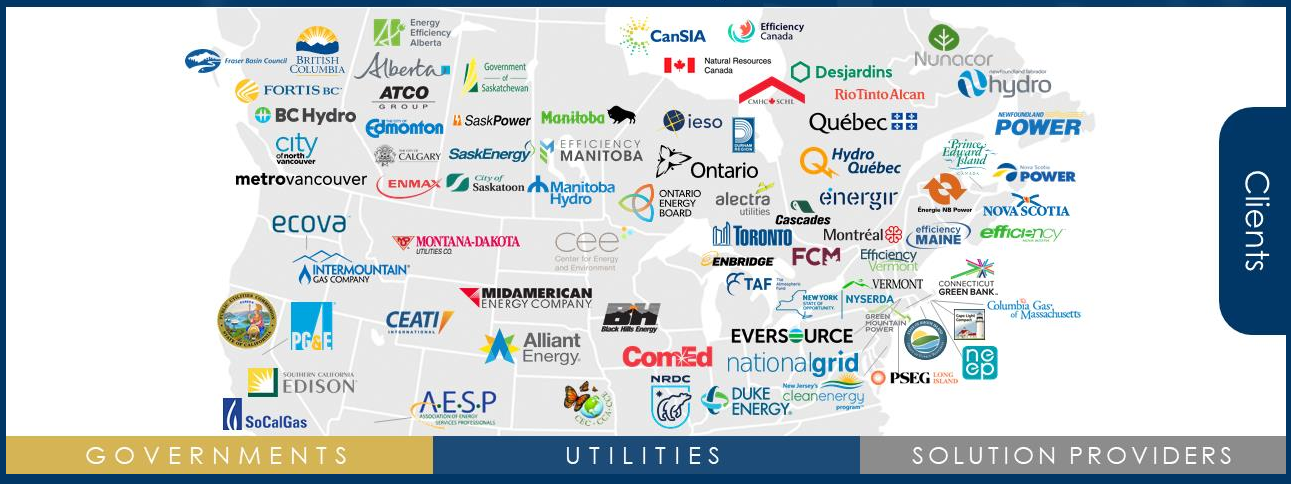


EXECUTIVE SUMMARY

Ground-source heat pumps (GSHPs) are typically the most efficient form of heating and cooling for buildings. For every unit of electricity a GSHP system consumes, it produces roughly 3-4 units of equivalent heat (or cooling), thanks to the solar energy naturally stored underground.

Because of these efficiencies, GSHPs can provide significant cost savings in the effort to decarbonize Canada's building sector. In cold climates in particular, GSHPs can greatly minimize winter peak demand – one of the greatest challenges associated with electrification in Canada. In the first phase of this study, we found such savings could reduce the need for large-scale expansion of Canada's electricity grid, which would more than offset their higher upfront costs. In fact, we found that **a reasonably ambitious adoption rate of GSHPs could save Canadians between $49 and $148 billion** relative to electrification through air-source heat pumps (ASHPs) alone, which comes down to about $40,000 in savings per installed GSHP system.

Although GSHPs can provide a net benefit, there is an important misalignment between the parties paying for these technologies (individual home and building owners) and those receiving the benefits (utilities and society). This report outlines effective policy solutions to capture the potential cost savings with GSHP adoption. In addition to these policies, utilities should update their cost-effectiveness analysis framework, including their avoided costs and value streams – which should reflect their decarbonization targets, so the benefits GSHPs bring to the grid can be accounted for more accurately.

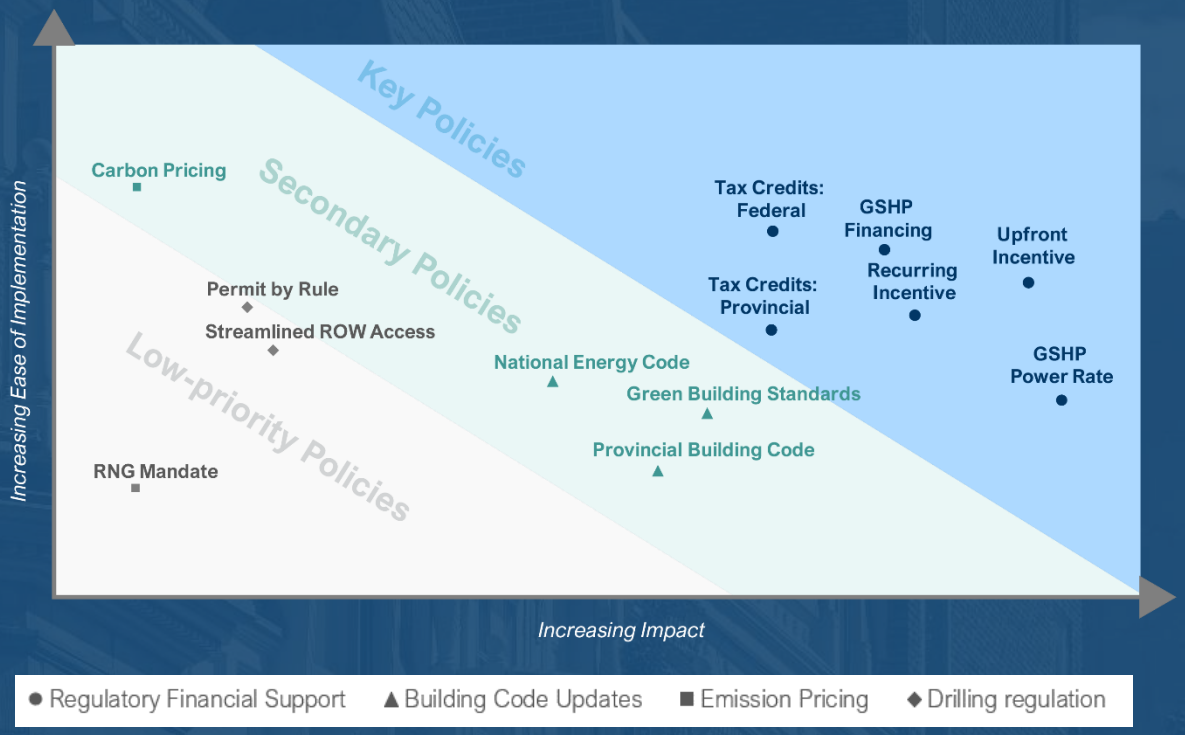
Our study finds that an optimal mix of policies aimed at increasing GSHP adoption could create a triple-win situation for Canadians: lower costs, increased GHG reductions from space heating, and a better alignment of costs and benefits. The following policies are key to unlocking the cost and environmental benefits of GSHPs for Canada, by transferring some of the social and grid benefits of GSHPs to those who must bear the capital costs:

Policy	Implementers	Timeline and Strength		
		Short (next 3 years)	Mid (3-10 years)	Long (10+ years)
GSHP-specific power rates	Utilities	+++	+++	+++
Recurring peak demand incentives or penalties	Utilities	+++	+++	+++
Federal tax credits	Federal Government	+++	++	+
Provincial tax credits	P/T	+++	++	+
Upfront incentives	Utilities, P/T	+++	+++	+++
GSHP financing	Utilities, P/T	+++	+++	+++

Federal Government | P/T Provincial/Territorial Government | Utilities

To perform the policy assessment, Dunsky investigated the policies implemented in four international jurisdictions leading in GSHP adoption. We mapped international policy successes and market barriers onto the Canadian context based on insights from a series of interviews with Canadian policy and industry leaders. Policy options were then assessed for their potential to impact GSHP adoption by addressing market barriers, recognizing the full value of GSHPs, and correcting the cost-benefit misalignment. In parallel, we assessed policy ease of implementation to find the policies that combine maximum impact and feasibility.

The results of this analysis are outlined in the full Policy Roadmap figure (section 5 of the report), summarized in the following prioritization matrix:



We recommend a combination of policies. Different policies address different barriers and will stay in the market for varying lengths of time. In addition, there are provincial and territorial variations in barriers and, therefore, effective policies. A blend of policies, such as substantial utility incentives combined with favourable building codes, will likely have more impact than one strong policy in isolation. Development of several policies concurrently can ensure broad market coverage and sustained support for GSHP adoption.

By focusing on the Key and Secondary Policies, federal, provincial, territorial, and municipal governments and utilities can tackle the most pressing barriers and recognize the significant cost savings that will come with increased GSHP adoption in Canadian communities. **Policy-supported GSHP adoption will benefit Canadian pocketbooks, electrical grid, and climate targets.**

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1. Beneficial electrification in Canadian decarbonization

Canada has set ambitious greenhouse gas (GHG) emission targets. Electrification of fossil-fuel processes is critical to meeting these targets and will require a diversity of technologies to achieve the low-carbon transition. Buildings account for 17% of Canadian GHG emissions, with a majority of those emissions driven by heating and cooling[1]. Electrification of space heating is a strong emissions reduction pathway due to the low-carbon intensity of much of Canada's electrical grid. Although some provinces have higher grid emissions intensities, most are working to decarbonize. As this work progresses, the emission benefits of electrification will continue to grow.

In addition to the benefits of reduced emissions, heating can be more efficient when electric heat pumps are employed; more heating and cooling can be done with an equivalent unit of energy when using heat pumps instead of electric resistance heating or fossil fuel systems. This efficiency can achieve cost savings for customers[2].

Electrification of heating can achieve significant benefits, including a reduction in environmental impacts, an increase in customer savings, and improved grid management. When electrification achieves at least one of these benefits without sacrificing the others, it is deemed beneficial electrification[3]. In Canada, electrification of space heating can achieve important environmental and consumer benefits as described above. There are a variety of technologies, including ground-source heat pumps (GSHPs), that could be employed to potentially mitigate adverse effects on the grid while reaching these benefits.

2. Reducing the cost of electrification

A major shift to electrification *could* require considerable expansion of the electrical grid to meet heating demand on the coldest days. There is a significant opportunity to mitigate some of the need for additional infrastructure by leveraging GSHPs, however. GSHPs have been present in Canada for decades and have a proven capacity to reduce energy use year-round. At low temperatures, GSHPs maintain their efficiency as they rely on the ground temperature as a heat source (and sink), which remains nearly constant all year

[1] Environment and Climate Change Canada. (2016). *Federal Actions for a Clean Growth Economy.* Accessed online: https://www.canada.ca/en/services/environment/weather/climatechange/climate-action/federal-actions-clean-growth-economy.html

[2] Natural Resources Canada. (2021). *Heating and Cooling With a Heat Pump.* Accessed online: https://www.nrcan.gc.ca/energy-efficiency/energy-star-canada/about/energy-star-announcements/publications/heating-and-cooling-heat-pump/6817

[3] Regulatory Assistance Project. (2018). *Beneficial Electrification: Ensuring Electrification in the Public Interest.* Accessed online: https://www.raponline.org/knowledge-center/beneficial-electrification-ensuring-electrification-public-interest/

round[4]. This constant efficiency significantly reduces the peak demand requirement and, therefore, the additional grid capacity required to electrify space heating.

One recent study prepared for the Canadian Gas Association[6], indicated that the transition to a heavily electrified economy relying on renewable energy sources could cost up to $1.4 trillion over the next 30 years. In a study Dunsky conducted recently[7], we found that **a reasonably ambitious adoption rate of GSHPs could save Canadians between $49 and $148 billion** relative to the original study's findings. That value climbs to nearly $500B in a scenario where GSHPs secure total market share[8]. These savings are due to the peak load and electric consumption benefits of GSHPs, which reduce the need for large-scale expansion of Canada's electricity grid. The savings from GSHP installations more than offset their higher upfront costs and can reduce the overall costs of beneficial electrification in many parts of Canada.

Although GSHPs can provide a net benefit, there is an important misalignment between the parties paying for these technologies (individual home and building owners) and those receiving the benefits (utilities and society). This study investigates solutions to address barriers to GSHP adoption broadly, maintaining a keen focus on correcting this misalignment through effective policy solutions.

3. Study scope

Given GSHPs' potential to provide considerable cost and emissions savings, how can Canada leverage this technology as we electrify our energy system?

This study explores the barriers holding back GSHP adoption in Canada, including the fundamental misalignment of the benefits and costs of GSHPs. To address these barriers, we explored policies in international jurisdictions that reduced local barriers and enabled higher adoption, as well as complementary technologies. This study identifies key policies that can support GSHP adoption in the residential, commercial, and institutional sectors in Canada.

Understanding these policies can allow Canada to unlock the benefits associated with GSHPs, in particular by making the electrification process more affordable.

[4] Some temperature variations generally occur at a monthly scale, but these variations don't have a significant impact on the efficiency of the system.
[6] Canadian Gas Association. Implications of Policy-Driven Electrification in Canada (October 2019). Available at: https://www.cga.ca/wp-content/uploads/2019/10/Implications-of-Policy-Driven-Electrification-in-Canada-Final-Report-October-2019.pdf
[7] Dunsky Energy Consulting. (2020). *The Economic Value of Ground Source Heat Pumps for Building Sector Decarbonization*
[8] Number provided for illustrative purposes only and does not reflect a realistic outcome as GSHPs will not be feasible in all buildings due to technical constraints and other factors.

1. Current market status

Ground-source heat pumps (GSHPs) have been available on the Canadian market for decades. The market is a relatively small portion of the heating market, with roughly 2% of all residential heating systems installed annually. However, as we heard from Canadian actors interviewed for this study, the market is established with a strong supply chain and an experienced workforce across the country.

2. Barriers to adoption

Understanding the market barriers and Canadian context is a key step in identifying potential policy solutions. Existing market barriers are slowing GSHP adoption despite the significant benefits to the customer, the electric utilities, and the society in general through GHG reductions. To understand the barriers facing GSHPs in Canada today, we interviewed policy experts and industry leaders.

We completed five interviews in February 2021 with interviewees representing multiple Canadian geographies, levels of government, and parts of the industry supply chain. We conducted each interview with a standardized structure to understand local barriers and insights on potential policy solutions.

The interviewees identified that the overall unaffordability of GSHPs is slowing adoption. This is due to high GSHP first costs as well as operational cost competition with low-cost and readily available natural gas. Customer awareness is a barrier due to perceived complexity or a lack of understanding of the technology and its benefits. Interviewees identified a similar awareness barrier in the construction and HVAC industries, where building design and development teams and contractors may be less familiar with GSHPs than with fossil fuel-powered heating systems or other types of heat pump technologies.

The following sections outline the top five Canadian market barriers identified by interviewees.

2.1 – High first cost

GSHP equipment and installation cost – together, first cost – are higher than incumbent technologies such as natural gas or heating oil furnaces and boilers, or even ASHPs. This is especially true for retrofit installations, where building heat distribution systems may require costly upgrades on top of GSHP on-site drilling and equipment installation costs. Interviewees cited high first cost as a key barrier preventing consumers from adopting GSHPs. Consumers may not have access to the capital required to pay first costs. If financing is available, some may use it to defer payments. Others may prefer to avoid debt load and interest payments, however, electing to install a technology they can pay for upfront.

Although not directly identified by interviewees, our previous research points to another, lesser-discussed reality inhibiting GSHP adoption – limited recognition of the full value of GSHPs, which include substantial grid benefits. This limited recognition is paired with a misalignment of the benefits of GSHP installations

(which are realized by society at large) and the costs (which are generally borne by individual home and building owners).

2.2 – Large price gap between electricity and fossil fuel

Inexpensive natural gas results in low incumbent heating equipment operational costs. The price gap between natural gas and electricity rates can lead to higher operational costs for GSHP despite the much higher efficiency of this technology. This disparity means that some consumers would pay more to install GSHP (first cost) compared to a natural gas furnace or boiler *and* pay more each month to heat their homes, even when taking the higher efficiency of the GSHP into account. Limited recognition of the grid value of GSHPs contributes to this disparity through electricity rates that do not recognize the system benefits of this technology.

2.3 – Competitiveness with other heating and cooling technologies

GSHPs also compete with other electrified heating equipment, including air-source heat pumps. It should be noted that most interviewees emphasized that there is room in the market for both types of technologies. Although the benefits of GSHPs (including high year-round efficiency and low noise) may persuade a portion of the market to pay the higher first costs of GSHP, others may choose to install the technology with a lower upfront cost. This is especially true when energy costs of GSHPs and ASHPs are similar, for example, if electricity rates do not include a peak demand component.

2.4 – Customer awareness

GSHP adoption has been slower in Canada than in any of the other jurisdictions included in this scan, and customer awareness is considered to be another significant barrier to adoption in Canada. Canadians remain less likely to know someone with firsthand experience of a GSHP. They may still consider GSHPs to be a new or unproven technology, which may make them hesitant to invest.

2.5 – Industry awareness

One Canadian interviewee noted that low GSHP awareness extends beyond consumers to the building design and construction industry. Developers, architects, engineers, and contractors with more experience with incumbent fossil-fuel technologies may not consider GSHPs when assessing heating and cooling system options. In addition, when GSHPs are employed in projects, their integration in the project and with other systems can present challenges when other parties are unfamiliar with the technology.

Regional Consideration: Drilling Permitting as a Barrier

Our international scan pointed to drilling regulations as a significant barrier to adoption in other countries due to the uncertainty of application review wait times and approvals. In the Canadian interviews, however, drilling issues were not identified as a leading concern. However, given the provincial and municipal nature of regulations, drilling can be a barrier to adoption in some regions. For example, in some jurisdictions, drilling operator approval can be difficult to obtain, and once obtained, compliance requirements can be onerous. Looking ahead, the permitting process could also become a bottleneck as GSHP demand increases. Therefore, while this is not a core Canadian barrier, it was maintained in the analysis.

1. International similarities

To understand how ground-source heat pump (GSHP) adoption can be accelerated in Canada, we looked to other jurisdictions which have experienced higher adoption.

Jurisdictions were selected for their high GSHP adoption rates and similarity to Canadian energy markets and climates. This approach ensures that the international policies identified have an increased chance of remaining relevant to Canada. Each jurisdiction has its distinct history, policy landscape, energy markets, and heating and cooling requirements. Collectively, the range of jurisdictions allows us to assess the types of barriers in each market, the impact of policies, and how the policies may apply in Canada.

To assess the similarity of the heating market, we compared the heating degree days of the capital city and the current unit cost of heating fuels, summarized in the table below. Canada is most similar to Sweden in heating degree days, with higher heating requirements than the other jurisdictions. Canada is most similar to New York State in terms of the heating fuel costs, where electricity is roughly four times more expensive than natural gas per unit of energy. European jurisdictions have experienced emission and energy pricing that has caused higher overall energy prices.

Table 1-1 Overview of climate and energy market metrics for Canada and selected jurisdictions

Jurisdiction	Heating Degree Days (18°C)[9]	Electricity (CAD/kWh)[10]	Natural Gas (CAD/kWh_{eq})[11]	Heating Oil (CAD/kWh_{eq})[12]	Electricity: Gas Ratio
Canada	**4,445**	**$0.14**	**$0.03**	**$0.09**	**4:1**
Austria	2,786	$0.32	$0.10	$0.09	3:1
Germany	2,959	$0.50	$0.08	$0.08	6:1
New York State	2,504	$0.19	$0.04	$0.10[13]	5:1
Sweden	4,036	$0.23	$0.17[14]	$0.14	1:1

[9] Average heating degree days of capital city airport, 18°C set as base temperature. Calculated using tool: www.degreedays.net
[10] Global Petrol Prices. (2021). *Electricity prices, June 2020*. Accessed online: https://www.globalpetrolprices.com/electricity_prices/
[11] Global Petrol Prices. (2021). *Natural gas prices, June 2020*. Accessed online: https://www.globalpetrolprices.com/natural_gas_prices/
[12] Global Petrol Prices. (2021). *Heating oil prices, 11-Jan-2021*. Accessed online: https://www.globalpetrolprices.com/heating_oil_prices/
[13] US EIA (2020). *Heating oil prices and outlook*. Accessed online: https://www.eia.gov/energyexplained/heating-oil/prices-and-outlook.php. Value converted to CAD using the Bank of Canada 2020 Annual Exchange Rate
[14] Statista (2019). *Natural gas prices for industry worldwide as of 2019, by select country*. Accessed online: https://www.statista.com/statistics/253047/natural-gas-prices-in-selected-countries/ . Value converted to CAD using the Bank of Canada 2019 Annual Exchange Rate

Our review found that these international jurisdictions have achieved higher adoption of GSHPs compared to Canada. For example, GSHPs are installed at an annual per capita[15] rate of 0.01% in Canada[16], while installations reached 0.23% in Sweden and 0.06% in Austria[17] and the US[18]. These jurisdictions have achieved high per capita adoption rates while facing similar energy markets and climates, highlighting the potential for Canada's adoption to grow under the right policy context. These efforts are achieving significant cumulative impacts. Today in Sweden, a long-time leader in adoption, 20 to 25% of its two million single-family homes are heated by GSHPs[19].

To further assess the similarity of markets, the first costs of GSHPs were assessed across the jurisdictions. Our research highlighted that, while bulk installations and flexible drilling regulations can achieve some substantial cost reductions, system costs remain high relative to incumbent heating and cooling technologies across jurisdictions.

While Canada's energy market, geography and climate are unique, there are jurisdictions with parallels that can highlight important lessons about which policies can have a meaningful impact on GSHP adoption. Local context is also integrated into the analysis to determine the applicability and relevance of policy options.

[15] World Bank. (2021). *Population, total.* Accessed online: https://data.worldbank.org/indicator/SP.POP.TOTL
[16] Email communication with HRAI. April 2021.
[17] European Heat Pump Association. (2018). *Heat pump sales overview.* Accessed online: http://www.stats.ehpa.org/hp_sales/story_sales/
[18] International Energy Agency. (2020). *Heat Pumps.* Accessed online: https://www.iea.org/reports/heat-pumps; AHRI. (2021). *Central Air Conditioners and Air-Source Heat Pumps.* Accessed online: https://www.ahrinet.org/resources/statistics/historical-data/central-air-conditioners-and-air-source-heat-pumps
[19] Swedish Centre for Shallow Geothermal Energy (2020). *Country Update for Sweden 2020.* Accessed online : https://www.geothermal-energy.org/pdf/IGAstandard/WGC/2020/01040.pdf

2. International solutions

2.1 – Finding international solutions

We employed two strategies to understand the enabling policies in international jurisdictions. The initial phase included desktop research of the GSHP-specific policies. This effort included a review of peer-reviewed articles, industry association publications, current and past federal legislation and international research projects.

To provide deeper context, we interviewed industry leaders in the GSHP sector in each jurisdiction. Ranging from industry to academia, experts were selected for their knowledge base, time involved in the industry, and familiarity with the policy context. Interviews were conducted in January 2021 to assess the local market, barriers to adoption, and successful policy solutions. The following table outlines the jurisdictions and organizations included in the study.

Table 2-1 Summary of interviewee role and organization from selected jurisdictions

Jurisdiction	Role	Organization
Austria	Academia	Graz University of Technology
Germany	Industry association	German Heat Pump Association
New York State	Government	NYSERDA
Sweden	Industry	NIBE Climate Solutions

2.2 – Connecting international policies to the Canadian context

Each market presents diverse barriers to emerging technologies such as GSHPs. To evaluate the success of policies implemented in each jurisdiction, we needed to understand the past and present barriers facing GSHP adoption. All barriers evolved with the market, and while it appears that no barrier has been fully eliminated, these jurisdictions made progress in accelerating GSHP adoption. The following table outlines the Canadian barriers, the jurisdictions which also faced this barrier, and policies employed to address them.

Table 2-2 Comparison of Canadian barriers to international jurisdictions and associated policies solutions

Canadian Barrier	Present in International Jurisdictions?				International Policies Addressing Barrier
	Austria	Germany	New York State	Sweden	
1. High first cost	✓	✓	✓	✓	Federal Tax Credit (US) Utility incentives (NY)
2. Large price gap between electricity and fossil fuel	✓	✓	✓		Building code renewable energy requirements (DE) Carbon tax (SE, DE)
3. Competitiveness with other heating and cooling technologies	✓	✓		✓	Building code performance (including peak demand) requirements (DE, SE, AT)
4. Customer awareness			✓	✓	Building code performance (including peak demand) requirements (DE, SE, AT)
5. Industry awareness					Not applicable: Canadian barrier not identified in international jurisdictions
6. Long and/or uncertain drilling permitting process	✓	✓		✓	Streamlined regulations (AT)

Four barriers overlapped between the international and Canadian findings, underlining the significant similarities in the market barriers between jurisdictions. Industry awareness was identified as a barrier by multiple Canadian interviewees, but not within the international scan. This difference may be due to the more advanced stage of international markets. Therefore, while policies did not directly address this barrier, lessons from the jurisdictions from the major policy themes can be applied to this barrier. In

addition, Canadian interviewees did not list long or uncertain drilling permitting processes as a barrier to adoption, unlike their international counterparts, but given the regional variation across Canada, this barrier is included in the analysis.

Our analysis of the interviews revealed that while a diversity of approaches was employed, the majority of policies fell into key themes that cut across jurisdictions. The policies can be captured in four major areas:

1. Regulatory financial support

International jurisdictions highlighted the effectiveness of sustained financial support for GSHP in reducing first and operational costs and increasing market awareness. Financial support can take a variety of forms (e.g. rebates, financing, tax credits, etc.); however, integrating this support into regulation increased its durability. This longevity builds awareness in the market of the technology and benefits while also transferring some of the costs to the beneficiaries of peak demand benefits.

2. Building code updates

Building codes were highlighted as a key policy area due to their broad impact and direct impact on building decisions within the construction industry and market. Internationally, these types of code changes were driven by efficiency and emissions. Building codes integrated diverse specifications that can be met by GSHP use, including requirements for renewable energy heating and cooling, heat recovery, and peak demand limits. These codes typically covered new construction, but the scan included one retrofit code at the regional level.

3. Emissions pricing

The business case for low-carbon heating and cooling, including with GSHPs, is challenged by the low cost of some fossil fuels, especially fossil natural gas. Within the jurisdictions reviewed, a number of international and national carbon pricing mechanisms aimed to correct for the cost of carbon emissions. This pricing influences the overall heating and cooling markets, particularly in Europe, where the anticipated future rise in the price of emissions is shifting heating and cooling technology choices today. This policy drives the market towards highly efficient, low-carbon solutions, including GSHPs.

4. Drilling regulation

Permitting wait times and uncertainty caused unique challenges for GSHPs. These issues were addressed through a streamlined process for GSHPs and alignment of industry best practices with regulation.

4. GSHP-Complementary Technologies

We assessed technologies that are complementary to GSHPs. By employing established or innovative technologies alongside GSHPs, buildings can achieve more efficient overall operations and improve the business case for GSHP adoption. In our review, we assessed technologies that are commercially available and/or in the pilot or demonstration phase across all sectors in this study.

1. Impact of technologies on GSHP adoption

1.1 – Benefits

The core benefit of these complementary technologies is that they improve the overall business case for GSHP adoption by reducing operational or capital costs. Broadly, these benefits are achieved by enabling GSHPs to provide more efficient heating and cooling to the building, to reduce total load requirement, or to otherwise optimize operation.

These technologies range in cost and implementation requirements, ranging from smart thermostats combined with heating sensors used to improve heating controls to heat exchangers used to recover heat from ventilation to reduce the GSHP heating requirement.

Employing these technologies generally provides the benefit of more efficient overall building operation while also improving the GSHP business case. In addition, there are some potential GHG emission reduction benefits in certain technologies that displace a portion of fossil-fuel water heating with low-carbon heating from the GSHP.

1.2 – Relevant policy areas

The complementary technologies operate in a diversity of ways, but ultimately, they address two of the Canadian barriers identified within the study. Through changes in the initial system design or optimized operations, these technologies address the capital and operational costs. This impact translates to the barriers: high first cost and the large price gap between electricity and fossil fuels.

We did not complete a barrier matching and policy analysis on the complementary technologies, as there are diverse considerations including overall cost-effectiveness and market-readiness that are beyond the scope of this study. However, our assessment did include a review of policies that could support these complementary technologies and their benefits. The review of the benefits and barriers highlighted that these benefits could be captured by addressing regulatory financial support and building code policies.

2. Findings

Complementary technologies exist that not only improve the GSHP business case, but can achieve improved overall building operations. This high-level review identifies that complementary technologies can tackle two key barriers in the Canadian market. Complementary technologies can be further leveraged by developing supportive regulatory financial support and building code policies. The details of our analysis can be found in Appendix A.

5. Policy Analysis

In this section we outline a list of policy options that will encourage uptake of GSHPs, allowing Canadians to reap the significant cost and emissions savings that can arise from the adoption of this technology. These options expand on the four policy themes identified in the International Solutions. For each policy, we analyze the relative impact and ease of implementation. Based on this analysis, we classify the policies into categories: key policies for government implementation, secondary policies for government consideration, and low-priority policies.

1. Policies under consideration

We expand on the four policy areas identified by highlighting the twelve policies relevant in the Canadian context. In each section, the barriers addressed by the policy area are identified using the following icons:

Icon						
Barrier Addressed	High first cost	Large price gap between electricity and fossil fuel	Competitiveness with other heating and cooling technologies	Customer awareness	Industry awareness	Long and/or uncertain drilling permitting process

1.1 – Regulatory financial support

Translating the international policy learnings to the Canadian context, there are a number of regulatory tools that can provide direct financial support for potential GSHP adopters. These financial supports can focus on the first or operational cost and can reach the market at different points in the customer journey. In addition to the direct cost benefits, the presence and promotion of these supports build awareness within the industry, and to a lesser extent, in the broader consumer market. Regulatory financial support can correct for the misalignment of the benefits of GSHP installations (which are realized by society at large) and the costs (which are borne by individual home and building owners). These policies should be designed such that the full value of GSHPs is recognized and redirected to the parties responsible for GSHP upfront and operational costs.

Policymakers should also consider their role in delivering and enabling financing programs that can at least partially alleviate some of the barriers associated with GSHPs (namely, high upfront cost). Utilities can offer financing options, such as low-interest on-bill financing, to increase accessibility and reduce the consumer financial risk. Enabling financing through legislation can improve access to home renovation loans. For example, Property Assessed Clean Energy (PACE) is a maturing financing model for clean energy upgrades, such as GSHPs. Provincial governments can enable these programs by developing necessary legislative frameworks.

Regulatory Financial Support

Policy	Description	Mechanism to Increase GSHP Adoption
Federal Tax Credits	Tax credits are deductions that reduce taxes paid on taxable income. Federal tax credits are tax credits offered by the federal government, and a single tax credit policy could apply to the whole country.	A tax credit that is equivalent to a portion of the purchase and installation cost of a GSHP would act as an incentive, reducing first costs.
Provincial Tax Credits	Tax credits are deductions that reduce taxes paid on taxable income. Provincial and territorial tax credits are tax credits offered by provincial governments, and therefore would need to be developed on a province-by-province basis.	A tax credit that is equivalent to a portion of the purchase and installation cost of a GSHP would act as an incentive, reducing first costs.
Upfront Incentive	In many jurisdictions, utilities and demand-side management program administrators offer ratepayer-funded incentives towards the purchase of technologies that provide electrical system energy or demand benefits. In some jurisdictions, governments or other actors may also fund incentives for technologies that provide other societal benefits, including GHG reductions.	A one-time incentive would reduce GSHP first costs.
Recurring Peak Demand Incentives or Penalties	Similar to one-time incentives, utilities and program administrators can offer recurring ratepayer-funded incentives that recognize the value of technologies that provide system demand benefits. Conversely, penalties (such as introducing or increasing the peak demand charge in a tariff) can improve the business case of a GSHP relative to other technologies.	Recurring incentives or avoided penalties would offset a portion of annual GSHP operational costs.

GSHP-specific Power Rates	Some utilities can offer rates that are technology-specific. For example, a growing number of utilities offer rates that apply to electric vehicle charging (often structured with lower rates during off-peak hours to incentivize charging at times of low demand). Utilities can offer electricity rates that recognize the unique use and benefits of GSHPs for the electrical grid.	GSHP-specific rates would reduce GSHP operational costs.
GSHP Financing	Financing options can allow homeowners to purchase a GSHP who would not otherwise be able to due to the high up-front costs or high-cost financing options. Accessible financing could include terms (e.g. low-interest loan) or the loan mechanism (e.g. on-bill financing, PACE financing).	Financing would reduce the up-front first costs by spreading out the payment while also reducing the total cost of the loan.

1.2 – Building code updates

In Canada, all three levels of government can impact building requirements, varying by geographic scope and stringency. Updates to the building codes at each level can support low-carbon heating and cooling and recognize GSHP grid benefits, depending on the requirements integrated into the update.

Building Code Updates		
Policy	**Description**	**Mechanism to Increase GSHP Adoption**
National Energy Code	The National Energy Code outlines minimum energy efficiency levels for new buildings. The code is developed through a consultation process that involves governments, industry, and other professional experts and was last updated in 2015. Once in place, the energy code can be adopted by any province or territory although this adoption is optional.	Increasing the stringency of energy efficiency requirements increases the cost of meeting these requirements using incumbent technologies, reducing the first cost gap. If the requirements are stringent enough, incumbent technologies may not be able to meet code and would effectively be banned from new construction. Codes can require renewable heating and cooling technologies, explicitly banning fossil fuel systems. Codes can also include GSHP-ready requirements (e.g., low temperature hydronic, forced air systems), reducing installation costs and increasing industry awareness.
Provincial Building Code	Provinces and territories are responsible for regulating the design and construction of new buildings. Although model building codes are developed nationally, they only apply to new buildings after they are adopted and enforced by provincial and territorial governments. These governments can also publish their own codes based on national model codes but with variations.	As with the National Energy Code, increasing the stringency of energy efficiency requirements reduces the first cost gap between these incumbent systems and GSHPs and can effectively ban some systems from new construction. They may also explicitly ban fossil fuel systems, or reduce installation costs and build industry awareness with GSHP-ready requirements.
Green Building Standards	Municipalities can use development policies or bylaws that exceed or complement code. They can tie building energy use or emissions requirements to the issuance of permits for new construction or retrofit activities[20]. They may also provide incentives (e.g. reduced fees, expedited approvals of permit applications) for activities that encourage sustainable development.	Green building standards can act like codes, making it difficult or costly to install low-efficiency or high-carbon heating systems. Alternatively, they can encourage high-efficiency or low-carbon installations through incentives that can reduce project costs or timeline, reducing first cost.

[20] Currently, Green Building Standards are the only building regulations that can target retrofits. In the Pan-Canadian Framework, however, the federal government committed to developing a retrofit code with completion targeted in 2022.

1.3 – Emissions pricing

Pricing carbon emissions can be focused on all emission sources or specifically on certain heating fuels. Emissions pricing recognizes the societal costs of fossil fuel combustion and the value of low carbon alternatives, including GSHPs, effectively shifting the market towards low-carbon options and correcting for market misalignments.

Emissions Pricing		
Policy	**Description**	**Mechanism to Increase GSHP Adoption**
Carbon Pricing	Carbon pricing imposes fees on carbon-based fuels. Carbon pricing can be done through taxes or a cap-and-trade scheme. In Canada, the Federal government has implemented a federal carbon pricing system across the country and planned for regular price increases until 2030. Provinces and territories have the flexibility of developing and implementing their own carbon pricing systems, so long as they meet the federal benchmark. For those provinces and territories that did not meet the federal benchmark or did not develop their own plans, the federal government has applied a federal carbon pricing scheme.[21]	Carbon pricing increases the cost of carbon-based fuels such as natural gas and heating oil. This increases the operational costs of heating systems that use fossil fuels, reducing the operational price gap between these systems and GSHPs
Renewable Natural Gas Mandate	Renewable natural gas (RNG) is typically produced from biomass and is compatible with pipeline infrastructure, making it interchangeable with natural gas. An RNG mandate would require that a designated percentage of natural gas sold by renewable natural gas.	RNG is less available and more expensive than fossil natural gas. Requiring a percentage of RNG could increase the cost of natural gas, increasing the operational costs of natural gas heating systems and reducing the operational price gap between these systems and GSHPs.

[21] Additional details can be found here: https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/putting-price-on-carbon-pollution.html

1.4 – Drilling regulation

Permitting for GSHP drilling and water use varies across provinces and territories. These policies can streamline the process for the access and drilling permissions that are necessary for GSHP systems.

Drilling Regulation		
Policy	**Description**	**Mechanism to Increase GSHP Adoption**
Permit by Rule for Groundwater and Utilities Protection	Groundwater and underground utilities are protected by provincial and territorial regulations defining how drilling operations can be completed. Permitting processes and wait times vary across each region, which influences the time and cost associated with drilling boreholes. In addition, there are regulations surrounding the use of groundwater resources, a key consideration for open-loop GSHP systems. GSHP drilling requirements can be relatively standard in some parts of the country. Due to this consistency, a permit by rule policy within the existing regulation would define the routine GSHP drilling activities, and groundwater uses covered under a general permit.	A permit by rule policy would streamline the application and permitting process for GSHP projects, reducing the associated time and costs.
Streamlined Right of Way (ROW) Access	Densely built urban areas present challenges to access drilling areas for GSHP boreholes. An additional challenge is to receive permitting for the drilling access due to private and municipal ownership of neighbouring property. Use of these spaces is possible for GSHP systems; however, navigating the permissions can be challenging. Municipalities can streamline access for GSHP systems by clarifying the right of way permitting process for the GSHP use case.	Similar to permit by rule, streamlined ROW access would reduce the time and cost associated with permitting. In addition, it may enable additional GSHP projects due to access to the underground resource where on-site resources are limited.

2. Analysis approach

We ranked all policies according to their expected relative impact (how much will a policy increase the adoption of GSHPs?) and ease of implementation (how challenging will it be to put the policy in place?). The criteria used to assess impact and implementation are listed below.

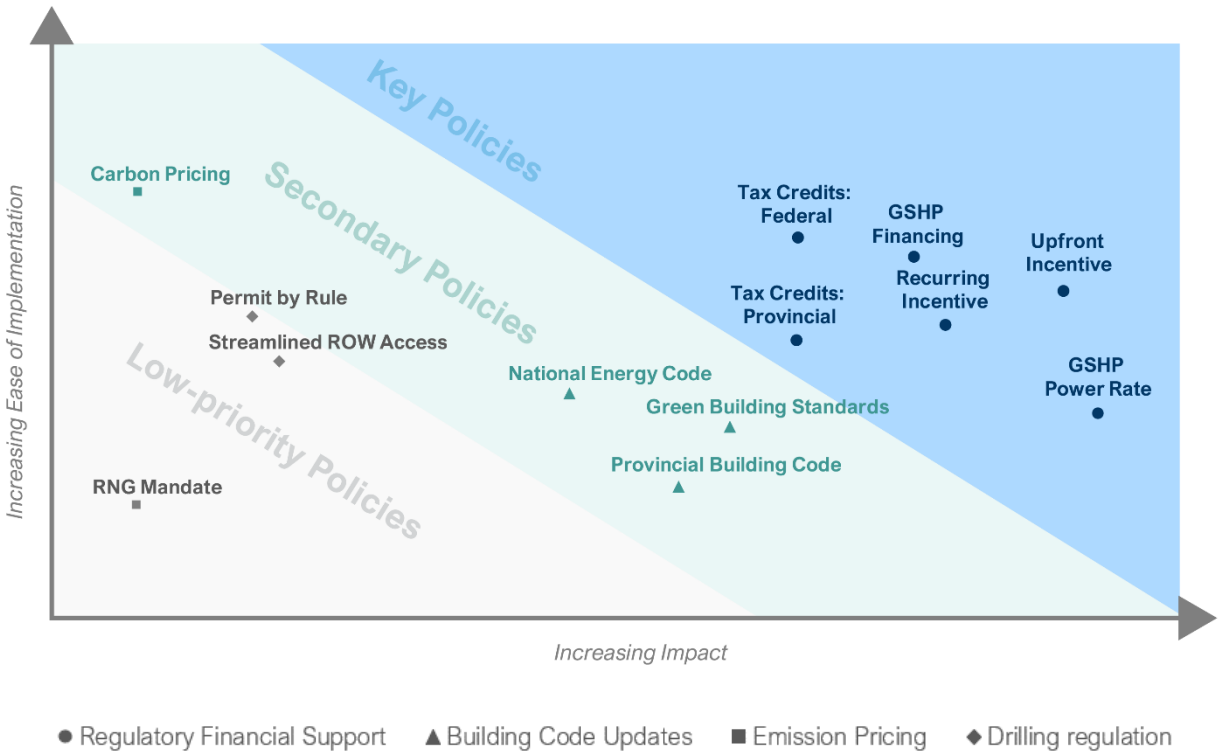
Impact
✓ Ability to address barriers ✓ Ability to specifically target GSHPs ✓ Ability to recognize and align the value of GSHPs with costs ✓ Policy longevity

Implementation
✓ Policy implementation time ✓ Market readiness level ✓ Ability to be rolled out at a national scale ✓ Industry and public stakeholder level of support ✓ Total cost of implementation

3. Analysis results

To understand the relative importance of each policy, we mapped the results onto an impact and implementation matrix, which is presented in Figure 1 The most promising policies have the most impact on GSHP adoption while being the easiest to implement, aligning with the top right corner of the matrix.

Figure 1 Impact and implementation scoring of each policy under consideration



Based on these results, we divided the list of policies into the three following categories: key policies to increase GSHP adoption, secondary policies, and low-priority policies.

Key Policies: These policies have the highest potential impact on GSHP adoption while also showing reasonable feasibility. Within this group of policies, those implemented by Utilities can effectively correct for the misalignment between GSHP costs and benefits and have the most impact on the market. The policies in this category are:

- Recurring Peak Demand Incentive or Penalty
- GSHP-specific Power Rates
- Federal Tax Credits
- Provincial Tax Credits

- Upfront Incentive
- GSHP Financing

Collectively, these policies have the largest overall impact on market barriers. These policies also benefit from established legal infrastructure and systems to expand or innovate on existing supports, easing the process of implementation.

Upfront incentives provided by utilities are impactful as they build awareness within the industry and customers, while also providing a financial incentive to address the first cost barrier that aligns with the timing of the customer purchase decision. GSHP-specific power rates are the most effective policy in transferring the significant peak demand benefits from the beneficiary (the utility) to the customer who pays for the system, while also addressing operational cost price gaps and GSHP competitiveness barriers. Recurring incentives (or penalties) offered by utilities can also transfer the peak demand benefits (or costs) to the customer and therefore improve GSHP competitiveness; however, their impact can be reduced if there is real or perceived uncertainty in future payments of the incentive. We found that tax credits at the provincial and federal levels have an equal impact due to their targeted nature, ability to address first cost, and build awareness. However, the impact is limited as tax credits do not typically include a mechanism for recognizing the recurring peak demand benefits of GSHPs. As an example, the New York State Senate is currently examining bill S3864 that would establish a tax credit of 25% for the purchase and installation of geothermal energy systems[22], in addition to the existing US federal tax credit of 26%.[23]

The availability of innovative financing for the purchase and installation of GSHPs can successfully reduce the first cost barrier by allowing home and building owners to spread the capital cost over many years, potentially generating a positive cash flow for owners immediately after the system installation.[24] These options can be particularly valuable to improve the accessibility of low-carbon heating and cooling options for low-income customers. For example, New York State offers a suite of financing tools to low-income residents for renewable energy renovations, including GSHP installations[25]. These tools include on-bill financing with low-interest rates, as well as short-term loans to bridge the gap between GSHP purchase and tax credit reimbursement.

For the policies in this category to be effective, they should be resilient. Sustained incentive and financing commitments are required from governments and utilities to ensure that the benefits of GSHPs continue to

[22] As of June 2021, the bill was being examined by the Investigations and Government Operations Committee of the NY State Senate (https://www.nysenate.gov/legislation/bills/2021/S3864)
[23] IRS (2021). *Energy Incentives for Individuals.* Accessed online: https://www.irs.gov/newsroom/energy-incentives-for-individuals-residential-property-updated-questions-and-answers
[24] Depending on factors such as financing rate and term, the energy savings generated by the GSHP can offset the annual loan repayment value, thus generating a neutral or positive cash flow for the owner.
[25] NYSERDA (2021). *Residential Financing Options*. Accessed online: https://www.nyserda.ny.gov/all-programs/programs/residential-financing-options

be recognized and valued. This will avoid a boom-and-bust cycle in the industry, which can be disruptive to adoption and workforce development.

Secondary Policies: These policies can shift the Canadian market to be more supportive of GSHPs and therefore increase adoption. However, these policies have elements that reduce their impact or that make them more difficult to implement. Therefore, these policies are not considered to be high-priority, but including a GSHP-specific lens in their design and implementation process could be crucial to assure they will help increase GSHP adoption and won't create any additional barriers for the technology.

- National Energy Code
- Provincial Building Code
- Green Building Standards
- Carbon Pricing

Within building policies, green building codes have the most potential for impact due to the ability for individual municipalities to be more aggressive than policies coming from the higher levels of government, as well as rising pressure from municipal emission plans and targets. Conversely, changes in the National Energy Code are seen to be easiest to implement because once a change is integrated, it is applicable across the country. Provincial building codes are seen to have a significant impact as they are a legal requirement, rather than their federal equivalent. However, it is expected that making these codes more favourable to GSHPs would require major province-by-province efforts with significant challenges to achieve stakeholder buy-in.

Our analysis found carbon pricing to have the highest implementation score of all policies assessed and the second smallest impact. The ease of implementation assessment is due to the fact that carbon pricing is an established policy that has already been rolled out across Canada. While carbon pricing can have a major impact on the price gap between electricity and fossil fuels, the policy has a limited overall impact since it doesn't significantly address the other main Canadian barriers, doesn't specifically address GSHPs, and doesn't have a clear ability to transfer social/utility benefits to the consumers. Therefore, while the federal carbon pricing policy currently in place could play a role in increasing GSHP adoption, we consider that the important amount of effort that would be required to make it more ambitious would be better spent on the key policies listed above.

Low-Priority Policies: These policies have the least impact and are the most difficult to implement. While there may be specific provincial, territorial or municipal conditions that could merit targeted efforts, these policies should be considered low-priority compared to the policies listed above.

- Permit by Rule for Groundwater and Utilities Protection
- Streamlined Right of Way (ROW) Access
- Renewable Natural Gas Mandate

Updating drilling regulations reduces some barriers to GSHP adoption; however, drilling is not found to be a leading barrier in Canada and, therefore, is lower in its overall impact. The provincial policy, permit by rule, is found to be narrowly easy to update because it is building on an established policy and would cover a larger jurisdiction once implemented.

We found emissions pricing to have the lowest potential impact of all the policy groups. Pricing emissions shift the overall market to lower carbon heating and cooling technologies; however, the market signals are small relative to the barriers facing GSHP adoption. An RNG mandate is challenging to implement as new policies would need to be established, and stakeholder resistance could be high.

4. Policy roadmap

In this section, we outline a roadmap for policy implementation. For each policy in the Roadmap, we indicate which actor is the primary decision-maker and which is the primary implementer. We also include a timeline indicating the suggested policy start date and duration. Timeline shading is used to signify the strength of the policy – we recommend that some policies start strong to provide a short-term boost to the market. These policies can then fade over time once the market reaches a sustainable level (supported by other, more permanent measures). We recommend that other policies start with a lower stringency that grows over time as the market and workforce build capacity. Finally, policies implemented by utilities are recommended to have a constant value over time to permanently correct for imbalances in the market – namely the misalignment of the grid benefits of GSHPs and their costs.

Table 4-1. Policy Road Map

Category	Policy Bucket	Policy	Implementer	Timeline and Strength		
				Short (next 3 years)	**Mid** (3-10 years)	**Long** (10+ years)
Key Policies	Regulatory Financial Support	Federal Tax Credits	Federal Government	+++	++	+
		Provincial Tax Credits	Provincial/Territorial Government	+++	++	+
		Upfront Incentive	Provincial/Territorial Government, Utilities	+++	+++	+++
		Recurring Peak Demand Incentive or Penalty	Utilities	+++	+++	+++
		GSHP-specific Power Rates	Utilities	+++	+++	+++
		GSHP Financing	Provincial/Territorial Government, Utilities	+++	+++	+++
Secondary Policies	Building Code Updates	National Energy Code	Federal Government	+	++	+++
		Provincial Building Code	Provincial/Territorial Government	+	++	+++
		Green Building Standards	Municipal Government	+	++	+++
	Emissions Pricing	Carbon Pricing	Federal Government	+	++	+++
Low-Priority Policies	Emissions Pricing	Renewable Natural Gas Mandate	Provincial/Territorial Government	+	++	+++
	Drilling Regulation	Permit by Rule	Provincial/Territorial Government	+	++	++
		Streamlined Right-of-Way Access	Municipal Government	+	++	++

Federal Government | Provincial/Territorial Government | Utilities | Municipal Government

Supporting Programs & Business Models

Policies provide a strong foundation for GSHP adoption, but they are part of a larger landscape of supportive activities. Key elements of this landscape include programs focused on education & awareness, workforce development & training, and technical assistance. These and other activities may align with or accompany policy efforts, but any recommendation on programs requires separate assessment and is out of scope of this study.

Innovative business models for GSHPs are emerging across Canada and internationally. New businesses are tackling the existing barriers by changing the traditional installation, financing, and ownership models of these systems. In one example, third-party energy developers install GSHP infrastructure then charge building tenants for the heating and cooling that they provide. By mirroring traditional utility business models - providing energy as a service while eliminating consumer investment in infrastructure - this model removes first cost barriers for individual home and building owners. We did not find that these novel approaches were driven by any particular policy approach in international jurisdictions. However, these businesses will benefit from a supportive policy landscape due to increased market awareness and capacity. Further, these emerging businesses could benefit from funding programs to support low-carbon businesses.

1. Key findings

An optimal mix of GSHP policies could create a triple-win situation for Canadians: Lower costs, increased GHG reductions from space heating, and a better alignment of costs and benefits. This mix should ideally be composed of consequential one-time incentives for home and building owners who choose to install GSHP systems, innovative financing to spread out the higher upfront cost over multiple years, and policies that recognize the recurrent value GSHPs provide to the electrical grid by reducing peak demand while increasing base-load demand compared to non-electric heating.

Regulatory financial support policies have the greatest chance of success. We found policies in this area to have the highest potential impact on GSHP adoption while also showing reasonable feasibility. These policies include federal and provincial tax credits, utility incentives, GSHP-specific electricity rates, and GSHP financing. In terms of implementation, both tax credits should be temporary measures aimed at solidifying the GSHP market, increasing workforce capacity and expertise, and building awareness of the technology. Utility incentives and GSHP-specific rates transfer value for the energy and peak-demand benefits of GSHPs from utilities to consumers, improving the alignment between the parties who pay for GSHPs and those receiving the benefits. GSHP financing can mitigate the higher upfront costs of GSHPs and improve their competitiveness with other technologies.

Policies led by Utilities can have the most impact on the market. Due to their direct access to consumers and the industry and their ability to impact both first costs and operating costs, utilities are in a unique position to influence the adoption of GSHPs. Policies implemented by utilities also have the inherent capacity to transfer some of the peak demand benefits of GSHPs – a reduced need for additional electricity infrastructures due to electrification – from the utilities to the consumers. This transfer restores some balance in the cost bearing of the GSHP systems and therefore creates favourable conditions for increased policy longevity.

Building codes can do a lot to create favourable conditions for GSHPs in new buildings. We found building code updates to be more difficult to implement while also having less impact compared to other policies. These policies are best suited to leadership by the different government levels, but careful attention should be paid to the design of these codes to maximize compatibility with GSHPs. Ensuring GSHP considerations are integrated into codes may not be a primary driver of GSHP adoption, but will avoid adding inadvertent barriers to the market because a GSHP lens was missing when new requirements were defined.

A combination of policies is recommended. Different policies address different barriers and will stay in the market for varying lengths of time. In addition, there are provincial and territorial variations in barriers and, therefore, effective policies. A combination of policies, like substantial utility incentives combined with favourable building codes, will likely have more impact than one strong policy in isolation. We recommend

the development of several policies concurrently to ensure broad market coverage and sustained support for GSHP adoption.

2. Next steps

The policy roadmap defines key focus areas and implementation timelines for GSHP-supportive policies. Each level of government has a key role to play. Collectively, these key policies can achieve the significant cost-saving and emission-reduction benefits of increased GSHP adoption.

	Federal Government	
Role	The Federal Government has set the stage to decarbonize Canada's economy. Federal action can make GSHPs more accessible to Canadians through tax credits, addressing core barriers. The federal government can continue the shift of the overall market to properly value GSHP benefits through Code considerations and carbon pricing.	
Strategic Policies	High Priority: • Federal Tax Credit	Secondary Priority: • National Energy Code • Carbon Pricing

	Provincial and Territorial Governments	
Role	The Provincial and Territorial Governments play a key role because they define both the provincial and territorial policies, as well as energy utility policies. They are responsible for the majority of the Key and Secondary Policies that can address GSHP barriers and some governments have significant influence over Utility policies. Prioritization of policies will depend on the local political, economic, and grid situation of the province or territory.	
Strategic Policies	High Priority: • Provincial Tax Credit • Upfront Incentive • GSHP Financing	Secondary Priority: • Provincial Building Codes

	**Utilities**
Role	Policies implemented by utilities can have a significant impact because utilities are most directly able to recognize and pay for the grid benefits of GSHPs. The electrical utility incentives and tariffs transfer the value and savings achieved in the electrical grid to the individual customers, while financing options enable utilities to mitigate and share the financial risk of installation.
Strategic Policy	High Priority: • GSHP-specific Power Rates • Upfront Incentive • Recurring Peak Demand Incentive or Penalty • GSHP Financing

	**Municipal Governments**
Role	Municipal governments have a more limited number of policy levers but can still exert important influence. Municipal governments are driving local, low-carbon building guidelines. Where GSHPs are considered and integrated, further adoption and key benefits can be achieved.
Strategic Policy	• Green Building Standards

Decarbonizing space heating and cooling in the building sector is an urgent challenge. Electrification offers an important low-carbon pathway that can achieve customer savings and emission reductions. Phase I of this study identified significant grid-level cost savings from employing GSHPs in the electrification transition. **Simply put, when a Canadian installs a GSHP today, the entire electrical grid and society benefits, to the amount of 40,000$ per installed system.** A coordinated policy effort can ensure that the market recognizes the value of that grid benefit.

Canada does not need to reinvent the wheel on GSHP policies. The policies identified in this study apply lessons from international GSHP-adoption leaders to the Canadian context and history. By implementing these Strategic Policies, federal, provincial, territorial, and municipal governments can tackle the most pressing barriers and recognize the significant cost savings. Policy-supported GSHP adoption will benefit Canadian pocketbooks, the electrical grid, and the achievement of climate targets.

7. Appendix

A. Complementary technologies summary

The following table summarizes the technologies reviewed in the study. This high-level assessment identifies key technologies that can provide GSHP system and building operational benefits by acting in a complementary fashion. Technologies were reviewed for their benefits, cost-effectiveness, and market readiness.

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
Domestic hot water pre-heating (desuperheater loop)	Domestic hot water tank with desuperheater	small residential multi-family commercial institutional	GSHP units take advantage of the heat generated by the indoor compressor by providing a desuperheater loop that pre-heats domestic hot water.	- reduction in energy costs due to reduction in hot water production energy required - reduction in GHGs, depending on energy source for hot water heating	Large price gap between electricity and fossil fuel	Building code	Commercially available	high
Envelope upgrades	Air-sealing measures	small residential multi-family commercial institutional	Reduction in total heating load requirement.	- reduction in first cost of GSHP system due to lower overall heating /cooling demand - reduction on operating cost due to lower overall energy requirement	High first cost Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	high
Improved controls and system efficiencies	System controls	multi-family	Optimize system operation by reducing the demand on heating and cooling systems. Heating reduction can be achieved by reducing heating loop temperature as much as possible, slow morning ramp up after a night setback, and improved controls of the outdoor airflow.	- reduction in operating costs due to optimized performance	Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	high

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
Improved heating controls	Smart thermostats and additional temperature sensors.	small residential	GSHP operation can be optimized by using smart thermostats and additional temperature sensors to improve controls (e.g., modulating controls, rather than turning on/off).	- reduction in operating costs due to optimized performance	Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	high
Hybrid natural gas and geothermal systems[26]	Sizing GSHP for the majority of annual heating needs with a natural gas boiler back-up	small residential multi-family commercial institutional	Optimization of GSHP utilization factor and of heating production based on grid capacity. GSHP can be sized for ~40-60% of peak heating load with a natural gas boiler as back-up, allowing the GSHP to provide ~60-90% of annual heating needs.	- reduction in first cost of GSHP system due to back-up of natural gas system - reduction on operating cost due to back-up in peak periods - reduction in GHG emissions associated with more significant use of the natural gas system	High first cost Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	medium
Pool pre-heating (desuperheater loop)	Pool heating systems	small residential multi-family institutional	GSHP units take advantage of the heat generated by the indoor compressor by providing a desuperheater loop that	- reduction in energy costs due to reduction in hot water production energy required - reduction in GHGs, depending on energy	Large price gap between electricity and fossil fuel	Building code	Commercially available	medium

[26] While hybrid systems using fossil fuels as a back-up can prove more cost-effective for home and building owners in some cases with current energy prices, they don't allow for a full decarbonization of space heating and can lock owners in a situation where a later upgrade of their heating system to reach 100% GHG reduction would be costly, technically complex, and not provide the same benefits to the electrical grid. Also, GSHPs don't technically require a back-up system, even in cold weather, contrarily to air-source heat pumps.

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
			pre-heats a swimming pool.	source for hot water heating				
Heat recovery from ventilation	Heat exchangers (e.g., cube, enthalpy wheel, "run-around loops," etc.)	multi-family commercial institutional	Heat exchangers are used to recover heat from the building's exhaust air to pre-heat outdoor air in ventilation systems. This pre-treatment of fresh air reduces the heating required by the GSHP.	- reduction in first cost of GSHP system due to lower overall heating /cooling demand - reduction on operating cost due to lower overall energy requirement	High first cost Large price gap between electricity and fossil fuel	Building code	Commercially available	medium (highly site dependent)
Heat recovery from air-conditioning systems	Chilled water coils are connected to GSHP, combined with heat recovery chillers. Applied in large buildings where simultaneous heating and cooling is required.	multi-family commercial institutional	Recovery of heat dissipated by the AC units. Chilled water coils are connected to GSHP instead of releasing AC unit heat outside, combined with heat recovery chillers where the condenser loop is maintained at a higher temperature and used for the heating loop, instead of simply releasing that heat to the outdoors through the cooling tower.	- reduction on operating cost (electricity) due to lower heating requirement (higher utilization)	Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	low to medium (highly site dependent)

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
Heat recovery from flue exhaust in hybrid fuel-GSHP systems	A baseload GSHP with a fuel-fired back-up where the cold side of the heat pump can be used to recover the latent heat from the flue exhaust of fuel-fired boilers	multi-family commercial institutional	Reach condensing-level efficiency. For hybrid systems in large buildings, where you have a GSHP that covers the baseload and a fuel-fired back-up, the cold side of the heat pump can be used to recover the latent heat from the flue exhaust of fuel-fired boilers (to reach condensing-level efficiency), usually using the chilled water loop. This approach is typically not simply used for preheating outdoor air.	- reduction in operational (electricity) costs due to more efficient operation	Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	low to medium (highly site dependent)
Terminal unit replacement	Replacement of radiators with models which can provide the same peak heating capacity at a lower loop temperature.	small residential multi-family commercial institutional	Replacement can improve the utilization time of GSHPs and increase their efficiency. Without terminal unit replacement, loop temperatures can be too high at certain times (usually when requiring significant heating capacity) and the heat pump either cannot produce such hot	- enabling GSHP installation - Improving GSHP efficiency	High first cost Large price gap between electricity and fossil fuel	Building code	Commercially available	low

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
			temperatures or has low COP.					
Thermal storage: short-term	Domestic hot water tanks	multi-family	Combining load of space and water heating to avoid curtailment and to reduce peak.	- reduction in peak demand due to load sharing with water tanks	Large price gap between electricity and fossil fuel	Building code	Commercially available	low
Thermal storage: short-term	Brick-based electric thermal storage	multi-family	Reduction in peak heating requirement.	- reduction in first costs due to reduced/shifted energy requirement - reduction in operating costs	High first cost Large price gap between electricity and fossil fuel	Building code	Commercially available	low
Envelope upgrades	Insulation measures	small residential multi-family commercial institutional	Reduction in total heating load requirement.	- reduction in first cost of GSHP system due to lower overall heating /cooling demand - reduction on operating cost due to lower overall energy requirement	High first cost Large price gap between electricity and fossil fuel	Regulatory financial support	Commercially available	low
Thermal storage: long-term	Borehole thermal energy storage	small residential multi-family commercial institutional	Seasonal storage of high-temperature water for use in heating months.	- reduction in operational costs due to thermal storage in peak heating/cooling seasons	Large price gap between electricity and fossil fuel	Regulatory financial support	Pilot or demonstration	low

Complementary Technology	Technology Examples	Sector(s)	Complementary action	Potential benefit(s)	Barrier(s) addressed	Relevant Policy Area(s)	Commercial-ization	Cost effectiveness
Thermal storage: short-term	Molten salt thermal battery Phase change material thermal storage	multi-family	Reduction in peak heating requirement.	- reduction in first costs due to reduced/shifted energy requirement '- reduction in operating costs	High first cost Large price gap between electricity and fossil fuel	Building code	Pilot or demonstration	low
Micro-district or community energy	Centralized geothermal loop for multiple dwellings	small residential multi-family commercial institutional	Sharing heating and cooling loads over multiple buildings.	- significant reduction in first costs due to shared boreholes	High first cost	Regulatory financial support Building code	Pilot or demonstration	N/A

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